The Engineer

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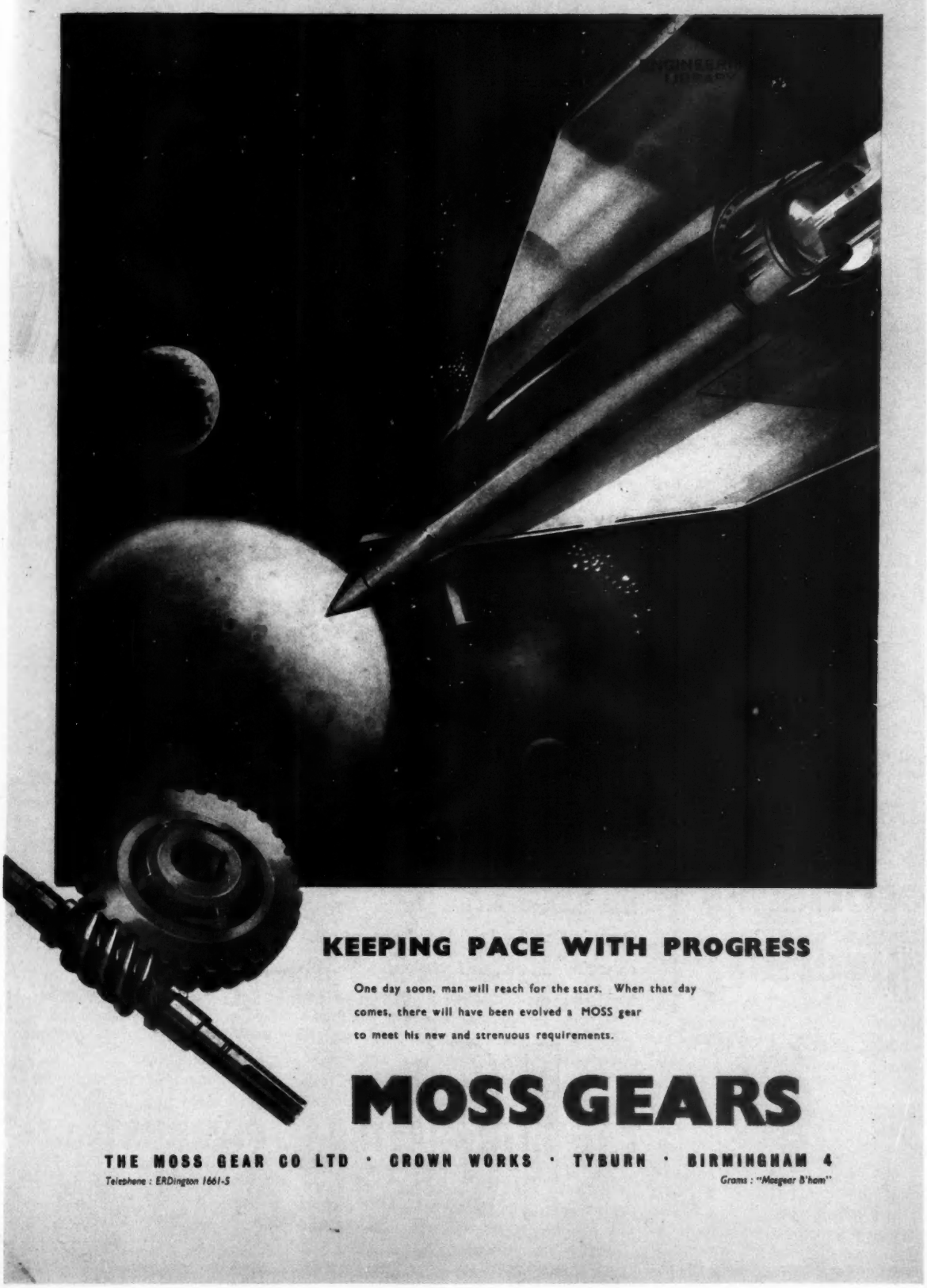

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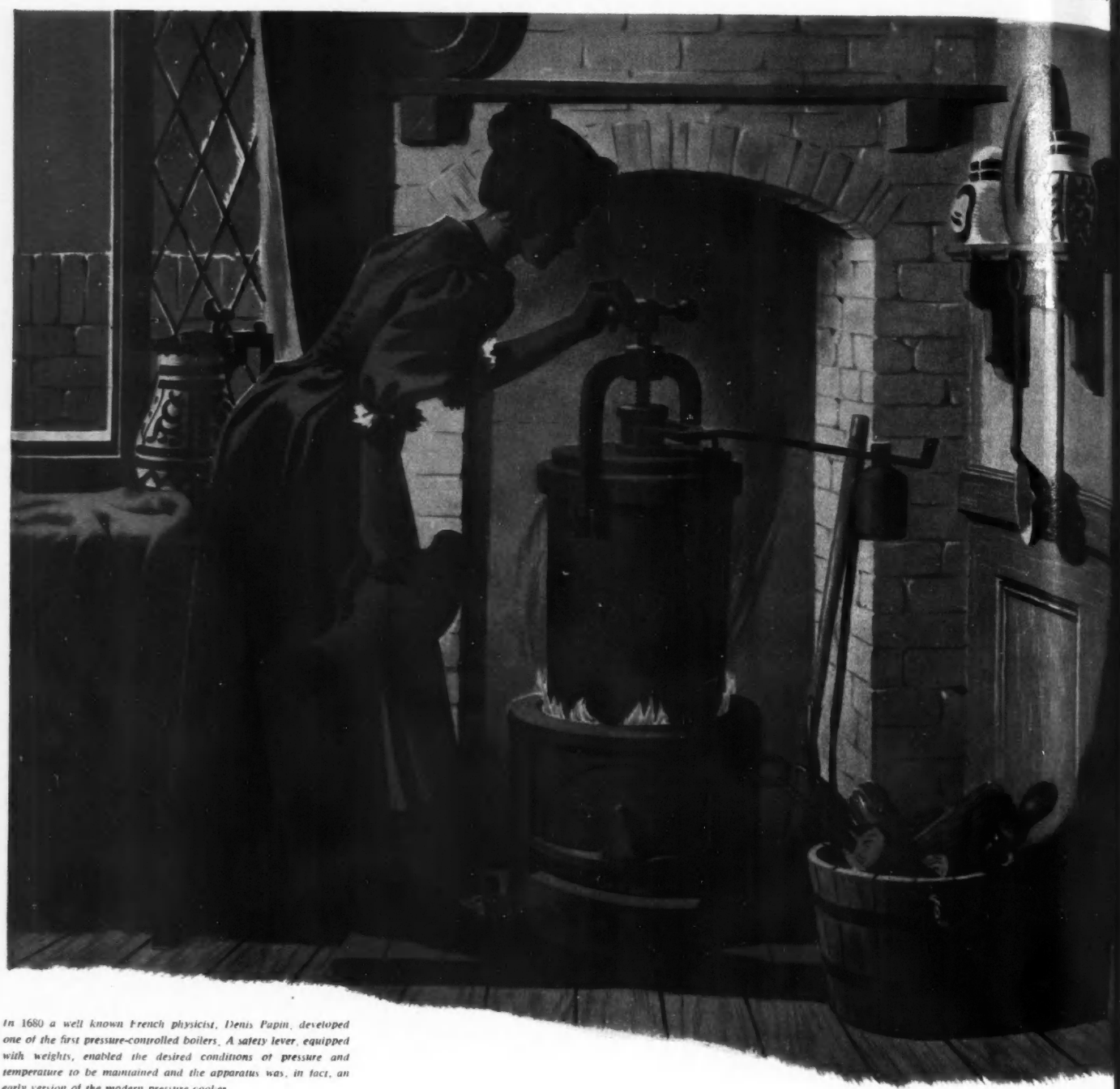

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THE ENGINEER

VOL. 202 No. 5262

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NUCLEAR POWER

Until last week it was probably no exaggeration to say that the majority of professional engineers were unable to form any clear ideas of their own about the future for nuclear power in this country. Admittedly the subject has received considerable publicity during the past year. But, although engineers and scientists working within this field have been quite emphatic in their opinions that the gas-cooled graphite-moderated reactor is the one that should be built for base-load power stations in this country, the reasons for their certainty and optimism have not been so apparent. The Symposium on Calder Works Nuclear Power Plant held on November 22 and 23 by the British Nuclear Energy Conference has done much to fill this gap. It was an excellent review of the design of Calder Hall and the B.N.E.C. is to be congratulated on its sponsorship of such a comprehensive and co-ordinated set of papers. Now that the subject is no longer one hedged about by security restrictions, and now that so much technical information has been released, it is as well that we should satisfy ourselves about the policy being pursued in the exploitation of nuclear energy. Is it right, for example, that so much reliance should be placed on the gas-cooled graphite-moderated natural uranium reactor ? Should the nuclear power programme be stepped up to exceed the proposals contained in the White Paper programme ? Can industry meet the requirements of such a programme ?

The first of these questions has really two implications : whether it is considered that sufficient work has been done to justify claims made for the present designs and for the first C.E.A. power stations ; and whether, in meeting an urgent and immediate demand for power this way, we are prejudicing future lines of development. The first of these aspects seems to have been amply answered by the papers that were presented at the Symposium. Calder Hall cannot in any circumstances be classed as a makeshift design. Few industrial plants involving completely new and unorthodox techniques can have received such a thorough study as has this one. It becomes evident from the papers that, right from the early days of the feasibility study, there has been an integrated and co-ordinated approach to the problems that have had to be solved. Even design features which may now appear inelegant and somewhat crude are that way from choice and not from any lack of consideration. The design team concentrated on solving the main problems that might prejudice success and quite rightly considered that there would be ample opportunity to produce a more refined design in future reactors. The result would appear to be that a very thorough study has been made of the fundamentals involved, and there is every reason to assume that the designs for the C.E.A. nuclear power stations should be basically sound. But to lead in a technology where large capital outlays are involved can be an uncomfortable position. There is always the suspicion that, while we commit large sums of money on our first choice, other countries may come along with better and more far reaching proposals resulting from a wider, and some might claim a more open-minded, development programme. It is in meeting this sort of criticism that Mr. Moore's concluding paper to the Symposium proved particularly valuable. The gas-cooled reactor looks to be a system capable of considerable development. There are the short term design improvements that will enable more highly rated plants to be built for the C.E.A. The use of thicker plate for the reactor vessel will enable higher gas pressures to be employed, and better canning materials and fuels will permit higher operating temperatures. But beyond these it seems that gas-cooled reactors operating at very high temperatures, e.g. 800 deg. Cent, with the fuel dispersed in the moderator, despite the technical problems yet to be solved, are a distinct possibility.

It is quite evident from the information now available that the original White Paper programme of 2000MW installed nuclear capacity by 1965 was very conservative. Even if no more reactors are built than were originally proposed it is likely that they will have considerably more capacity than was forecast. But should the proposed number of stations be increased ? Sir Claude Gibb looks upon this as a challenge that industry can meet. To meet it, however, will demand extremely careful planning and some revolutionary thinking. As Mr. Jack Thompson pointed out, the boiler-making industry will have to reorientate itself completely to meet the requirements of the Calder Hall type of station. No longer can the major fabrication work be done under tight control in the firm's own shops. Instead the centre of gravity is shifted to the site, where fabrication must be carried out under a degree of supervision and control that is quite new. But the effects of this go even further back into our basic industries. A nuclear power station is likely to take twice the amount of steel that is required by a conventional station of corresponding output, and of this steel a far greater proportion will be required in the form of plate. Because of the difficulties of maintenance and inspection of plant subjected to high irradiation, fabrication methods must be of the highest quality and carefully controlled, and the same standards must carry right back to the selection of raw materials. However good the designs for

nuclear power plants may be, the success of the nuclear power programme will depend to a large extent on the quality of plant fabrication and construction. It is not an easy specification to meet when so much needs to be done on site. It can be met by careful and realistic planning on the part of all sides of industry involved, and in fact this must be done if the nuclear power programme is to be accelerated.

THEIR LORDSHIPS DISCUSS EDUCATION

To the strict Party man debates in the Lords no doubt lack fire. There is little cut and thrust about the discussions that take place in what the Commons refer to, rather disrespectfully, as "another place." Yet on some subjects the debates are all the better for its absence. The Lords, for example, are never in better fettle than when discussing education. For the Lords have all been educated, whereas, when reading Hansard, it sometimes seems permissible to doubt whether all those who sit in the Commons have had that advantage. Last week the Lords, at a time when the Commons was highly excited about certain events in Egypt, discussed with care the subject of engineering and scientific education. They brought out in true perspective a number of matters of interest. Lord Simon opened the debate and, in so far as such a word can be used of a speech before the Upper House, proved provocative. He stressed in particular how much Russia is doing to train engineers and to what an extent and at what a speed the output of the engineering industries is expanding there. He emphasised that Russian steel output, before the war far below that of Britain, was now more than twice ours; that it is increasing at a rate of about 10 per cent per year; and that by 1960 it will be about three times that of Britain. He referred to the impression created upon Lord Citrine's mission by Russian technical achievements in electrical engineering and mentioned Russian ability to manufacture hydrogen bombs. This great rate of advance, he said, came from "the terrific concentration on the education of physicists and engineers." In Britain each year we trained engineers to graduate standards at the rate of not more than 7000 a year, "whereas the Russian total is certainly 80,000 or more, and is increasing very fast indeed." In his reply the Lord President of the Council, Lord Salisbury, announced the Government's plans for University expansion. The details are printed elsewhere in this issue. Broadly, the plans are intended fully to meet requirements estimated over the next ten to fifteen years by the Committee on Scientific Manpower, whose report was recently published. They are particularly encouraging because they provide not for a "once and for all" expansion of facilities, but for a continuous and progressive increase in the number of technologists undergoing training.

But it was not in reference to the main lines of the debate that anything strikingly original was said. The urgent need to expand the output of trained technologists has been apparent to the engineering industry for years past. Ever since the war, the "Situations Vacant" columns of the engineering press have remained far better filled than the "Situations Wanted" columns. The demand has been and remains apparently insatiable. The Government, indeed, would have laid itself open to violent criticism if it had not acted energetically to aid the expansion of universities and colleges. What was brought out in the debate was not so much the need to expand facilities for educating technologists as the difficulty of getting sufficient young men to take up technology as a career. That difficulty is already serious; and in the longer term it has become essential for this country's economic survival that a higher proportion of young men should choose technology as a career. What stops them doing so? Though the universities so far have proved rather unwilling to alter the "balance" between the arts and humanities on the one hand and the sciences and technologies on the other—there has, according to Lord Chorley, been an increase of scientists and technologists relative to our total university population of only 8 per cent since the war—the blame can hardly be placed there. There has been room and to spare for more technological students in recent years. The trouble, as industry and the major engineering institutions have recently realised, lies further back. Boys still at school need to be interested. That is why industrial firms have, in various ways, been taking an interest in schools by providing apparatus, endowing scholarships and the like, and why Institutions are acting in various ways to interest boys and schoolmasters in engineering as a career. But there may be more to it than that. Several speakers in the Lords debate went out of their way to stress that engineering was as respectable a profession as any! If the brighter intellects amongst boys passing on to universities and colleges are to be attracted to engineering as a career the status of engineers within the community clearly needs raising. For none amongst the Lords would have thought similar remarks necessary had education for law or medicine or accountancy been the subject of debate. There is a great deal of misconception in the minds of members of the lay public about what engineers actually do. It needs to be removed.

But if the Lords gave their approval to the Government's intention urgently to press forward the expansion of technological education they were not wholly uncritical of certain related Governmental activities. Lord Falmouth drew attention to the element of unfairness consequent upon the Government's ability to confer indefinite deferment of military service upon any youngster with a degree who becomes a scientific officer in the Government service. He went on to challenge whether scientists and engineers in Government service were as well employed as they might be and voiced the suspicion that some of the research being done was "stale" and had ceased to be productive. He asked in fact whether it was not time that some of the research establishments set up during the war should be closed down. It is a matter of great difficulty to determine whether he is right. For much of the work done is wrapped in secrecy; and much never gets published not because there is any reason to keep it secret but because the process of getting it "security cleared" is a nuisance and there appears to be little active encouragement (possibly rather the reverse) offered to officers to make public work that they have carried out. Certainly the matter raised by Lord Falmouth is one that the Government should look to.

The Engineer

100 Years Ago

(NOVEMBER 28, 1856)

"RAILWAY ACCIDENTS"

"We think it quite impossible that the ensuing session of Parliament can pass without something being done to put a stop to, or to go towards putting a stop to, railway accidents. There are certain regulations desirable, about which there can be no question. We cannot now stop to enumerate them all; but foremost amongst them may be noticed the necessity of having a man at every level crossing and at every siding, and in long ones at each end of every siding. There should also be a man at every signal . . . Another necessary precaution is, that every train, whether passenger, goods, coal, or ballast train, should have attached to it apparatus which would enable the guard or attendant to communicate with the engine-driver. An arrangement for this purpose might be very strong and very rough in the case of goods, ballast, and coal trains, but yet might be made so as always to give notice when any part of the train became by accident detached from the rest. . . .

"We recollect that, in the Exhibition of 1851, an apparatus was shown for communicating between the guards and drivers of a railway train, in which the side chains were used as conductors, and the alarm given was a shriek from the steam whistle, which could not possibly fail in being heard. . . . Sir W. Cubitt's leather strap passed through rings along the train, with a gong on the engine; and Mr. Brunel's elevated, but much despised post (which nobody would accept), on the tender, are plans which have been tried on express trains only, and with more or less success. . . . We argue not for any special arrangement, but for some one being applied to *all* trains; and that no time be lost that some one of the modes already proposed be adopted, even if not *perfect*, until something better is discovered. . . . Parliament has a duty to perform in the matter of railway accidents, and our advice to the public is, to let it have no rest until that duty be performed efficiently."

A Seven Day Journal

University Building Projects

THE Financial Secretary to the Treasury, Mr. Henry Brooke, made an announcement in the House of Commons, on Wednesday of last week, about the Government's plans to meet the greatly increased demand for university education, in view of the national need for more university-trained scientists and technologists. The universities, he said, had already made proposals to the University Grants Committee, which, taken together, would increase the number of students from 84,000 in the academic year 1955–56 to 106,000 by the mid-1960s. Of that increase, it was expected that about two-thirds would study science or technology. That increase, Mr. Brooke continued, could not be met without building much new accommodation of all kinds, and the Government was convinced that that was a sound long-term investment. Accordingly, the Chancellor of the Exchequer had given authority for university building projects up to the value of £10,400,000 to be started next year, £12,000,000 in 1958, and a further £12,000,000 in 1959, over and above the large sums required for the expansion of the Imperial College of Science and Technology. These amounts, Mr. Brooke added, were instalments of what would be needed over a longer term ; they compared with " starts " of £4,800,000 for the current year, which meant that the present rate of " starts " was to be more than doubled. But, Mr. Brooke continued, large though the increase was, the Government believed that the universities should be encouraged to expand even more. The University Grants Committee had said that a larger expansion would be desirable if resources could be made available, and it was anxious to invite the universities to consider still further expansion to meet national needs. The Government, Mr. Brooke stated, was giving further thought to that matter in consultation with the committee.

Electrical Research and Food Production

ON Monday and Tuesday of this week a conference was held in London on " Future Research on Applications of Electricity to Increase Food Production." It was arranged by the Electrical Research Association, and the attendance was limited to a company numbering about sixty, including specialists in agriculture, horticulture and fishing, and others interested in the development of land and natural resources. The aim of the conference was to obtain frank opinions as to the lines to be followed in future researches rather than to hear details of present practice. It will be remembered that the E.R.A. established its rural electrification section in 1938, and that research programmes on various aspects of the matter have been continuously followed since then. A field station was set up at Shinfield, near Reading, in 1945 to provide increased facilities for this research (see THE ENGINEER, May 15, 1953). In view of the increasing importance of farm mechanisation as a factor in augmenting food production and of the rapid extension of electrical distribution systems in this country and abroad, the E.R.A. felt it was desirable that future research should be discussed more widely than is necessary for the year-to-year operation of the work. One of the conference sessions considered Commonwealth and Empire requirements. The discussion was introduced by Mr. J. E. Mayne, the Colonial Liaison Officer at the National Institute of Agricultural Engineering. Mr. Mayne urged that there was a strong case for detailed local surveys of power potential in the Commonwealth, including such sources as mineral, hydro-electric, biological and solar. Large national surveys already carried out had led to major power projects in some countries, but for providing power to isolated communities and farms much remained to be done. One possible direction for research would be towards lowering the cost of distribution to individual premises. There was a great need, Mr. Mayne said, for more knowledge of water management and for means of automatic control of water table and artificial precipitation.

The Engineers' Guild

THE annual report of the general council of the Engineers' Guild for the year ended September 30 last records the total membership of the Guild as 4505, a net increase of fifty-six during the year. The period covered by the report completes ten years of the Guild's active existence since its revival after the war. The membership when the Guild was restarted was 250. The report comments on the Guild's many activities during the past year. Among these is reference to discussions with officers of the British Transport Commission concerning the Commission's professional engineering staff. As a result of these discussions, the report says, the Commission has undertaken to discuss informally at any time with the representatives of the Guild any matters concerning the professional status and other interests of chartered engineers. This " channel of communication " will not, of course, affect the existing machinery of negotiation. Another matter mentioned in the report is that, during the year, the Guild's professional interests sub-committee considered seventy-three problems of individual members, and either advised on the action which should be followed or arranged for the matters to be taken up by the Guild on behalf of the members concerned. In addition, many matters of general interest to the engineering profession were again considered and action taken where necessary ; such matters included the training and remuneration of professional staff, the amount of annual leave, salary scales in various industries, and the organisation of the nationalised industries. The report is to be presented at the annual meeting of the Guild, which will be held at Grosvenor Hotel, Victoria, London, S.W.1, on Wednesday, December 12, at 5.45 p.m.

Nuclear Power for Ships

IN proposing the toast of " The City and Port of Bristol," at the recent annual dinner of the Bristol Steamship Owners' Association, Sir Donald Anderson, the deputy chairman of the P. and O. Company, stressed the need for the Government to concentrate its attention on the development of nuclear power for merchant shipping. All the early work in this field, he said, had been related to the application of nuclear power for the generation of electricity, but now the efforts of the Harwell atomic research station should be devoted towards the production of a reactor suitable for installation in a merchant ship rather than in a ship of the Royal Navy. The importance of the merchant navy in the economic life of the nation and the dangers of dependence upon oil as a fuel indicated that an early start should be made with the equipping of merchant ships with nuclear reactors as a source of power irrespective of their degree of efficiency. Time would effect improvements, Sir Donald added, and he was sure that time and money thus expended would not be wasted.

I.E.E. Christmas Lecture

THE Institution of Electrical Engineers has announced that the eleventh annual Christmas lecture for older school children will be delivered by Mr. J. F. Coales, M.I.E.E., of Cambridge University Engineering Laboratory, on the subject of " The Evolution of Automation." The lecture will be given in the theatre of the Institution, at Savoy Place, Victoria Embankment, London, W.C.2, on Tuesday, January 1, 1957, at 3 p.m., and repeated on the following day at the same time. The Institution says that for its Christmas lectures every effort is made to evolve a suitable technique for their delivery to school children, so that the lectures may prove of maximum benefit and interest. In his forthcoming lecture, Mr. Coales intends to recall that the replacement of physical labour by machines has been going on continuously throughout the centuries, first by the use of gravity, water and wind power, later by the use of solid fuels, and now by the use of nuclear power. The underlying principles of automatic control will be discussed and demonstrated by a simple electrical control system. There is no charge for admission to the lecture, but application for tickets (stating the day for which they are required) should be made to the Secretary of the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Street Lighting and Safety

IN a speech at Newcastle upon Tyne, on Thursday of last week, Mr. W. Robinson, lighting officer of the British Electrical Development Association, emphasised that good street lighting was not a device to speed up traffic. It was, he said, a necessary condition for traffic and pedestrians to be able " to live together at night." There was a tendency to forget, Mr. Robinson continued, that class " A " lighting of streets was based on adequate visibility, without headlamps, for up to 30 m.p.h. The first job of those responsible for improving street lighting was to get on with the modernisation of the lighting of restricted roads where three-quarters of all accidents occurred. Projects for other roads must wait until that was done, and until the even higher standard of illumination could be afforded that would be required for safety at speeds over 30 m.p.h. Making a plea for better street lighting, Mr. Robinson said that he was not seeking to minimise the problem of the 55,000 people killed or seriously injured annually on the roads ; it was in relation to these that the importance of better street lighting must be judged. It would be miraculous, he added, if any lighting system ever obtained 100 per cent approval, for that would involve an installation, the colour of which was perfect, which had no glare, the columns of which pleased every æsthetic sense, or which by a " merciful intervention," required neither columns nor wall fittings ! Since no such lighting existed, or was ever likely to exist, Mr. Robinson remarked, there had to be found the best compromise between cost, technical performance and public acceptability.

Commissioning of Calder Hall No. 1 Reactor

By K. L. STRETCH,* M.A. (Cantab), A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E.

No. II—(*Concluded from page 726, November 23*)

Commissioning the first half of Calder Hall "A" power station—that is, No. 1 reactor and its associated generating equipment—is described from when it was taken over by the Operations Branch, U.K.A.E.A. in mid-May until its official opening by Her Majesty the Queen on October 17, 1956. The first two months covered charging the reactor with uranium, low-power physical tests to establish the nuclear characteristics of the reactor and the calibration of the control system and full-scale flow testing at zero power. After testing the burst cartridge detecting equipment, power operation with steam dumping was started early in August. By the end of the month steam conditions were satisfactory and steady enough to start commissioning the generating plant, and by late September the half-station was fully commissioned and steadied out at moderate power to await the opening.

Loading to Critical Size

As soon as it had been established that the reactor and its essential safety and control circuits were in full working order a start was made on charging the reactor, on the morning of May 19. During this initial stage it was very desirable to keep the form of the charged portion of the reactor cylindrical. This was to ensure that the trace of the approach to critical curve, in which the ratio of number of channels charged to count rate, plotted against number of channels charged, was very nearly a straight line. This enabled accurate information of the progress of the operation to be obtained, as the curve cuts the number of channels axis at the critical size (Fig. 8). In addition, it was most important that the first critical reactor should be cylindrical in form when obtained, to facilitate the nuclear measurements and calculations which are then necessary for determining the characteristics of the completed reactor. As the normal charging routine deals with blocks of sixteen channels at a time, this was only used for the first large mass of metal in the centre of the reactor. Thereafter, hand loading was adopted to enable a single ring of channels to be charged at a time.

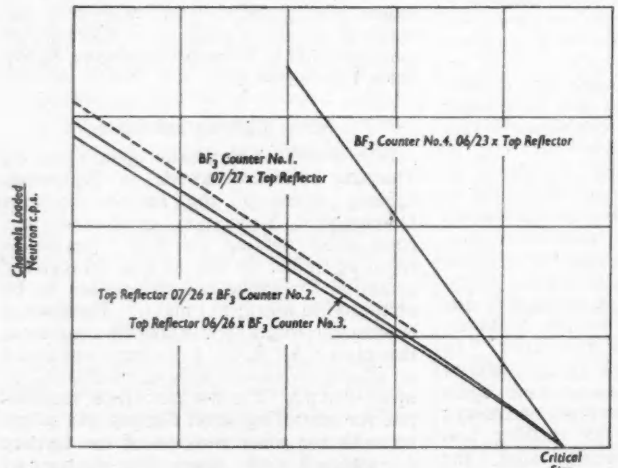

BF_3 Counter No.1. 07/27 x Top Reflector
BF_3 Counter No.4. 06/23 x Top Reflector
Top Reflector 07/26 x BF_3 Counter No.2.
Top Reflector 06/26 x BF_3 Counter No.3.
Channels Loaded Neutron c.p.s.
Critical Size
Channels Loaded

Fig. 8—Approach to criticality of No. 1 reactor

Monitoring the approach to critical was carried out by counters inserted at different points in the reactor. Initially, as the count rate was extremely low, the best readings were obtained from, and main reliance had to be placed on, counters in the centre of the reactor. As charging proceeded these were, of course, the first to jam, by the count rate rising above the limit of the instrument; but at each stage of the process there was some overlap between inner and outer counters to enable the curve to be normalised and a continuous plot of the approach to critical obtained. During this stage, as the reactor was sub-critical and only just critical at the end, a special gearbox was inserted in the frequency converter drive which allowed fast withdrawal of the control rods. As this was available, it was possible to charge with the control rods inserted and at appropriate stages stop the process, withdraw the rods quickly and obtain a count. The initial quantities of metal charged between counts were large, of the order of tons, but as the trace showed that the critical point was being approached smaller quantities were charged, until at the end the unit was four channels of twenty-four elements. As the critical point was approached the counters inside the reactor jammed in turn. Reaching criticality was indicated by the external counters and reactor low power meters starting to double instead of settling down to a steady rate. As, however, at this stage the reactor was only very slightly super-critical, doubling times were extremely long, and it was there fore necessary to go just over the critical point to establish that it had indeed been achieved.

By 7.15 p.m. on May 22 the last points on the trace in Fig. 1 had been obtained and a definite doubling time confirmed, and from this information it was clear that we had obtained a critical reactor.

Measurement of Reactor Parameters

At this stage the charging process was stopped to enable a series of measurements to be made to establish the basic physical parameters of the reactor. First, the radial migration areas were obtained by increasing the radius and therefore the reactivity of the reactor in small stages, and measuring the doubling times. When this had been done the measurement of the radial Laplacians and extrapolation length was carried out by inserting a series of foils across selected diameters, irradiating them to a given flux and measuring the subsequent reactivity. This enabled plots of the flux across the reactor to be obtained, from which the necessary information could be calculated. Similarly, with the axial characteristics, strings of foils along two vertical axes of the reactor were irradiated and from these a plot of the flux distribution axially was also obtained. This information was necessary to enable the physical constants of the reactor to be calculated, and a revised estimate of the excess reactivity of the fully charged reactor to be made.

After obtaining the basic parameters it was originally intended to measure the effect of introducing a certain amount of enriched uranium in case the reactivity of the reactor was low, and also of steel absorber in case the reactivity was high. As, however, the reactor went critical earlier than expected there was an indication that the reactivity of the fully charged reactor would probably be higher than expected, and it was, therefore, decided not to carry out the experiment with enriched uranium. The experiment with steel was carried out by increasing the excess reactivity of the reactor slightly, then inserting at an appropriate point a channel of steel and measuring the reduction in reactivity which this channel caused. A flux plot across the steel was also carried out, so that a measure of the flux distortion would be available. After this work had been completed a measurement of the absolute flux in the reactor was obtained by irradiating a sodium carbonate capsule. This was necessary to enable the calibration of the installed sub-critical and low-power indicators to be checked with their theoretical values.

Loading to Full Size

At this stage a mass of physical information had been obtained which Harwell and the research departments needed some time to digest to enable the necessary physical constants to be deduced. In the meantime, the work of loading to full size was carried out.

At this stage as the reactivity of the reactor was being raised above the limit of 0·2 per cent reactivity (K) for which fast withdrawal was considered safe, the temporary gearbox was removed from the control rod system and the permanent one installed. This ensures that the control rods can only be withdrawn at a speed of about 1cm a minute and, therefore, that the maximum rate at which reactivity can be released in the reactor is low, about 2×10^{-4} K per second. However, when this modification had taken place it was clear that any technique which involved withdrawing rods for counting purposes would lose a great deal of operating time, and a revised technique was adopted for carrying out the charge to full size safely, based on a further series of approaches to critical. Sufficient rods were fully inserted, initially twenty-six, and disconnected from their drive mechanisms, and with these holding the reactor well below critical the normal plots of approach to critical were started, using counters in the reactor reflector. As well as these rods which were left fully inserted, further rods were held up on the control mechanisms in the normal manner and operated by the normal reactor safety circuits, so that at every stage there was ample shutdown capacity in hand in case criticality was inadvertently reached due to a fault developing in the monitoring instruments or failure to react to the indications correctly.

Although it was advantageous to keep the reactor still roughly cylindrical in form to obtain satisfactory approach to critical

* Works Manager, Calder Hall

plots, at this stage it was decided that the charging mechanisms should be given a thorough testing and the charging was, therefore, carried out in complete charge hole groups, that is sixteen channels at a time, or in half groups.

As the charging of the reactor continued, a revision of the estimate of the number of rods necessary to hold the reactor barely critical at full size was possible by watching the progress of the approach to critical graphs. Fig. 9 shows the last of these traces

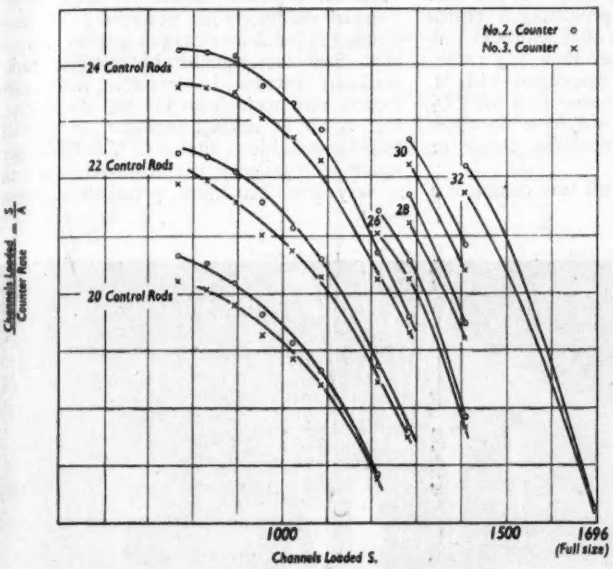


Fig. 9—Loading to full size: approach to criticality with different numbers of control rods inserted

as the reactor was approaching full size. By then it was clear that the number of rods necessary for holding it at full size was thirty-two. The additional rods were quite easily inserted in the latter stages by means of the fine control rod system, while obtaining sufficient overlap between the traces to ensure that the progress in approach to critical was fully monitored.

By this time it was quite clear that the reactor had, in the cold state, a greater reactivity than was originally estimated, and also that the control rods were considerably more effective than the initial predictions had suggested. As, however, the nuclear calculations had not been completed, it was impossible to separate these two factors completely at this stage; but as the next experimental work was the control rod calibration, a first rough estimate of the number of rods needed had to be made to ensure that any modification to the control rod pattern after the calibration would not upset the calibration curve. It was, therefore, decided to carry out the control rod calibration with fifty-two rods effective, the remaining ones which had been provided being withdrawn and hung out of the reactor.

Calibration of Control Rods

The calibration of the control rods was carried out by two methods. In the sub-critical region, counts were taken at each stage as the rods were withdrawn, and these with halving and doubling times at the balance points gave a shape of the curve which then required normalising. At the balance point before the major part of the calibration took place, foils were inserted across a cell containing a control rod and irradiated, so that the flux distortion caused by the control rods could be estimated.

Having done this, the reactor was then sealed, as the technique adopted for calibrating the control rods was to pressurise with air and balance the loss of reactivity due to the neutron absorption of the nitrogen in the air by withdrawing the rods. The reactor was first pumped down to about 12cm Hg absolute pressure of air and the calibration curve started from this point with a balance point of the rods. At each stage then the reactor was shut down by running the fine rods in, altering the conditions and running the fine rods out to the paralleled position to obtain a doubling time. From the balance point a second point was obtained with all rods withdrawn a small distance to give the first doubling time and measure the excess reactivity which the rods had released. A measure of the pressure coefficient was then obtained by increasing the pressure of air by 10cm Hg and measuring the increase in doubling time. After this the reactor was pressurised with air approximately equivalent to 50cm of rods and the rods then withdrawn that distance to restore the reactivity. A fresh measurement of doubling time indicated any change in reactivity at the end of the stage.

By this means, continually stepwise measuring the pressure coefficient and then moving the rods to compensate for a given change in pressure, the calibration curve shown in Fig. 11 for the complete set of rods was established. When the full curve had been obtained—that is, the rods had been run fully out and the reactor fully pressurised with air—a check of the calibration of the fine control rods was obtained by running these in and repeating a similar process in rather large steps for the fine rods alone. Lastly, a pair of the central control rods were inserted to measure their effect. These measurements were needed not only to measure the effectiveness of rods at different points in the reactor, but also to establish whether there was any interaction between rods. The shape of the calibration curves is generally similar for different groups of rods, the position and number only affecting the total capacity.

By now the nuclear physicists had completed their calculations on the physical data and so two estimates of the installed

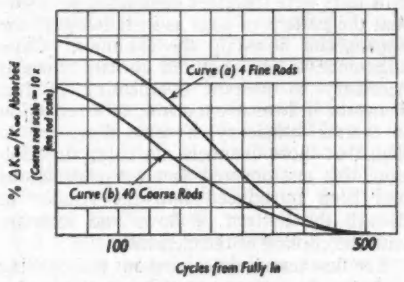


Fig. 11—Control rod calibrations

reactivity of the reactor in the cold condition were available, one from these calculations and the second from the build up of the control rod calibration curve. It was, therefore, decided to insert steel absorbers to adjust the reactivity to a figure leaving a slight amount in hand in case any of the poisoning coefficients proved larger than was expected. With this reduction in excess reactivity it was also possible to reduce the number of control rods needed for operating the reactor. It was decided from the information available that forty were capable of controlling the reactor. This would be sufficient for operating purposes, as the reactor could under the worst cold, unpoisoned condition be shut down with ample negative reactivity. The pattern of rods chosen is shown in the picture of the top of the reactor when this had been repatterned (Fig. 10).

It will be noticed that the control rods are concentrated towards the centre of the reactor. More installed reactivity has been left than is needed for operating purposes; a final assessment is not yet possible, but subsequent experience suggests that this is not an ideal pattern for efficient operation. As, when the reactor is more accurately trimmed, sufficient capacity can

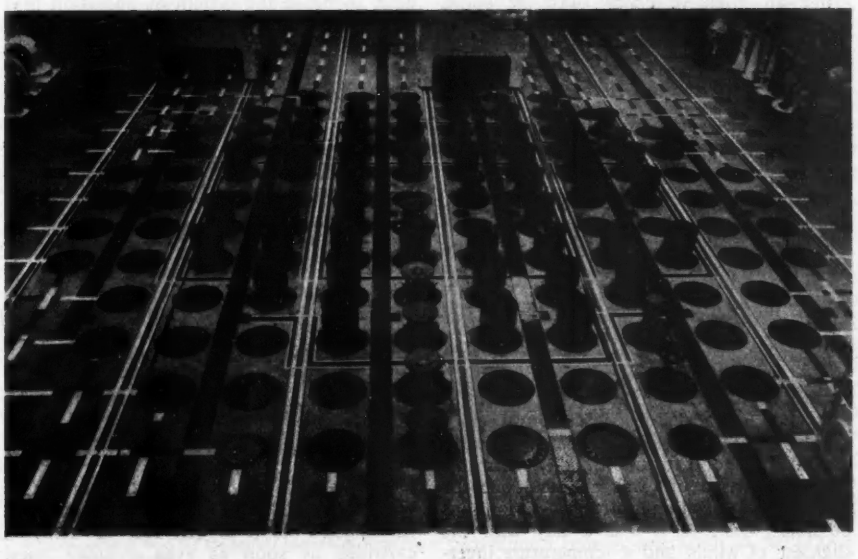


Fig. 10—Control rod pattern adopted after calibration of control rods

be obtained with the rods more evenly distributed, arrangements are being made for adopting an improved pattern in future. At this early stage of the programme the decision was made to err on the side of safety, as the rods have a greater effectiveness near the centre of the reactor, rather than final efficiency.

Air Flow Tests

By now the reactor was charged with its final load of uranium and full scale air flow tests were therefore conducted to ensure that the pattern of gags as installed gave the appropriate flows up the channels. Close adherence to the required coolant flows is necessary to prevent overheating of fuel elements, if flows are too low, or a reduction in thermal efficiency, if some flows are so high that those channels run cold. In addition, this test ensured that no obstructions had been introduced into the reactor to disturb the pattern of flows and interfere with the cooling of the elements.

The flow tests were carried out by installing a group of anemometers (fifty) in the outlets of the fuel element holes and running the circulators up to full speed. Measurement of the flows through the anemometers was obtained outside the reactor by existing installed counter gear operated by the vanes of the anemometers interrupting a light circuit between a bulb and a photo-electric cell. As soon as one block of fifty readings had been obtained, the circulators were run down and the anemometers repositioned until a complete set of flow readings over the entire 1696 fuel element channels had been obtained. Where any anomalous results were noted, rechecking took place to ensure that accurate patterns of gas flows could be deduced.

CO_2 Tests

As soon as the air flow tests had been completed and while the results were being checked with the theoretical predictions, the reactor was put through a full-scale CO_2 test. The technique of charging the reactor with CO_2 is first to evacuate as far as possible (to approximately 27in Hg vacuum) before introducing the CO_2, to reduce the air impurity in the CO_2 as low as possible. This evacuation and charging is carried out two or three times before the reactor is pressurised with CO_2. On this initial charge the pressure was not taken directly to full working, but at about 50 lb per square inch gauge an intensive check over the entire circuit was carried out to look for leaks. Wherever these were found suitable remedial action was taken before the reactor and its associated gas circuits were blown up to full pressure. As soon as a reasonable standard of gas tightness had been obtained the reactor was taken to full working pressure, and the circulators started and given a 100-hour run under full working conditions. During this a check on the leakage rate was maintained and all associated and installed mechanisms were operated, but the main object of the exercise was to note the stability of the internal components under the full gas flow conditions of the circuit.

When the run was over the excess CO_2 above atmospheric pressure was blown off. Advantage of this blow off was taken to carry out a very strict check on whether release of CO_2 was likely to cause a health hazard. By good fortune the day when this test was carried out was an ideal one for making the health hazard as serious as possible; that is, it was a day with the slightest of winds and a temperature inversion which would encourage the CO_2 to reach ground level as quickly as possible. In addition, a cold charge was blown off, whereas under normal conditions the CO_2 to be discharged will be hot, while the ventilating fans were deliberately cut off during the experiment. A complete ring of CO_2 detecting points were deployed inside and outside the reactor extending from immediately alongside to several miles downwind. Of all these places only one showed any detectable rise in CO_2 concentration, despite a larger and faster release of CO_2 than would normally be carried out, and even this was well below anything approaching a health hazard. As it is known that with CO_2 the chemical hazard is higher than any radio-activity which may be associated with it, this was a welcome indication that the CO_2 discharge arrangements will have no effect on the surrounding area, either inside or outside the works fence.

As soon as the blow off was complete a series of tests was carried out on all the ancillaries, such as charge and discharge gear, to prove the system of operation in a CO_2 atmosphere and observing the necessary purging routine. Most of these went smoothly, except for minor repairs; but at one or two stages it was decided that further work could profitably be carried out to simplify and expedite the routine. After this was complete the entire reactor circuit was purged to enable a full-scale inspection to take place inside to ascertain whether any signs of looseness or vibration were apparent. Fig. 12 shows a picture of the inside of the reactor at this stage, the inspection showing that the reactor had stood the full blowing tests without any signs of trouble.

It should be noted that throughout these early stages of the programme the irradiation level had been kept low so that there was no hazard involved in working inside the reactor.

Burst Cartridge Detection Tests

The next stage was to test the equipment which was installed for detection of burst cartridges. As it is desirable to detect a cartridge as soon as even a small burst occurs, the sensitivity of the device must be established under normal operating conditions. As the tests were carried out at low power it was necessary to install in the channels quite large foils of enriched uranium, the larger size and higher enrichment producing in the lower flux a similar effect to what a small exposed area of uranium would in the full working one. The tests were carried out at atmospheric pressure. During the tests it was discovered that the sensitivity of the apparatus was satisfactory and would enable the bursts to be detected at very early stages, when an exposed surface of uranium of 1 square millimetre has occurred; but after a time the build-up of argon activity was so high that the signal-to-background ratio gradually became intolerable. When correction was made from the test conditions, that is air at normal pressure, to normal working conditions, that is CO_2 at 100 lb per square inch gauge, it was clear that even with a very low maximum permissible argon figure in the CO_2 circulating gas, the background would still be far too high.

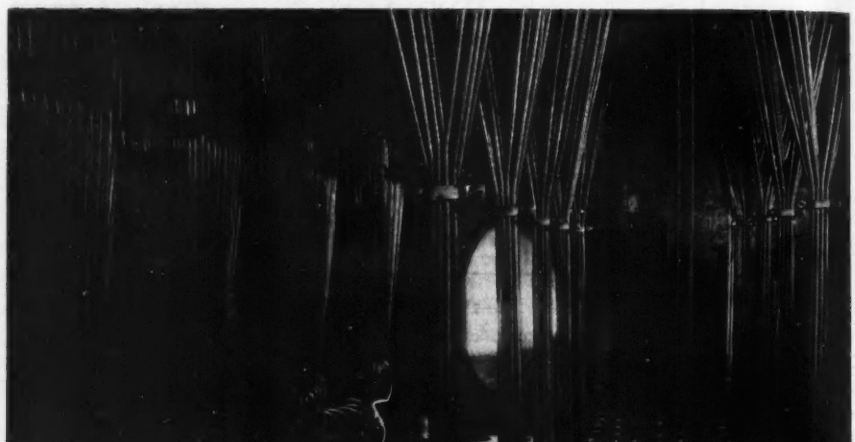


Fig. 12—Interior of reactor showing part of the pipework for the burst cartridge detection gear

While the system was being modified to deal with this problem it was found that the locking arrangements on the top spiders of the cartridges were not satisfactory. These problems could therefore be dealt with at the same time; so during the ensuing week the commissioning programme was halted and an intensive effort was devoted to clearing any outstanding work and tidying the plant ready for power operation.

As soon as this work was finished the burst cartridge detection equipment tests continued. The signal-to-background ratio had been sufficiently improved to enable the channel detectors to operate quite satisfactorily. A higher power run was also carried out to enable the duct detectors to be calibrated. These detectors work on the main outlet gas streams, and any activity is much diluted at this point.

This was the last of the tests which could be carried out at low power and therefore the final preparations were put in hand for running the reactor at high power. Special fuel elements with startup thermo-couples were installed and the system was then finally sealed and refilled with CO_2.

Workup of Reactor Power

Before allowing the reactor to work under its own power it was warmed up by passing steam into the heat exchangers and circulating the warmed gas by the circulators. This was to enable the temperature coefficient of the reactor to be obtained by balancing the control rods both in the cold and the hot condition. In addition, when the reactor had reached a steady condition of about 140 deg. Cent. (284 deg. Fah.) a recalibration of the control rods was carried out over the sub-critical and just critical region, to measure any difference in the effectiveness of the rods in the hot and cold conditions.

As soon as this had been completed a start was made in allowing the reactor to operate at power by withdrawing the rods and allowing temperatures and powers to rise to a moderate figure, that was initially a top can temperature of approximately 300 deg. Cent. (572 deg. Fah.). At this stage all the steam produced was fed over into the dump condenser, both because it was not of a suitable quality for feeding to the turbines and also to enable the staff to concentrate on getting the reactor settled before worrying about its inter-relation with the generating equipment. As soon as an appreciable increase in power had taken place, the reactor was allowed to stabilise off to enable the xenon coefficient to be measured, by noting the movement of rods necessary to hold it at this power level as the xenon poisoning built up. As soon as this was clear, the safety valves were floated on the heat exchanger boilers. The reactor was then ready for pushing up to somewhere near its rated power and temperature. As the reactor was operating quite steadily it was decided to raise the can temperature immediately to 350 deg. Cent. (662 deg. Fah.), so that the reactor could steady out in a condition where it was producing steam suitable for commissioning the turbines. It was also found that this was necessary to enable a reasonable heat load to be extracted from the reactor, as reduction of the top temperature very quickly stopped the high-pressure steam system evaporating and overloaded the low-pressure one, unless the total heat load was dropped. The reactor was therefore left for about fourteen days operating at a steady load, about 120MW, on the dump condenser, while operators made themselves fully familiar with the operation of the reactor and the heat exchangers, and the safety section carried out extensive surveys to detect whether there were any areas of the reactor where radiation or CO_2 might cause a health hazard. A few areas were ascertained where the radiation level was perceptible and remedial action by introducing additional shielding was immediately taken, so that in none of the main working areas of the plant was there a radiation hazard. No points have yet been detected in which there is any CO_2 hazard.

Commissioning the Generators

At the end of August the reactor had been operating steadily at part load long enough for the next stage, the commissioning of the turbo-alternators, to be put in hand. The steam conditions were adequate for this purpose and the first turbo-alternator was, therefore, run up mechanically on August 20th. Once the overspeed tests and bearing inspection had been satisfactorily completed, drying out of the alternator was started and proceeded satisfactorily so that by the end of the week it was possible to carry out the normal electrical tests on the alternator. During Monday, August 27th, the alternator protection was set up and the alternator was ready for paralleling by the evening. The first alternator was paralleled on to the bars at 10.25 p.m. on August 27th. Over the next few days the turbo-alternator was worked up in load and a certain amount of minor repair work carried out on some of the turbine house valves. As soon as No. 1 was complete the commissioning of No. 2 turbo-alternator followed, and after an interval No. 3 was also commissioned, to ensure that ample spare capacity was available for the official opening.

In view of the official opening by Her Majesty on October 17th, it was decided that the reactor and its associated generating circuits should be settled down at a moderate figure, rather than make any attempt at this stage to see how much could be got out of it. Fig. 13 is a flowsheet showing the conditions in the heat circuits at which the reactor was allowed to settle down and operate quietly until the official opening had taken place. This allowed a period of about one month while the reactor and circuits were operating under a smooth and steady load, to enable the operators to become thoroughly at home with their plant and for any minor defects to be put right. The load was dropped on a number of occasions deliberately to allow items of plant to be taken off and minor maintenance work carried out on them, and a few modifications to be installed which practice had shown were necessary. In addition, a number of unscheduled trips occurred as some items of equipment showed their temperaments. These were, however, singularly few in view of the complexity of the safety and control circuits, and all were steady by the opening day.

Since the official opening the reactor has been successfully worked up to full design power, and experimental work is now in progress to determine the best working pattern for the reactor and the maximum possible output.

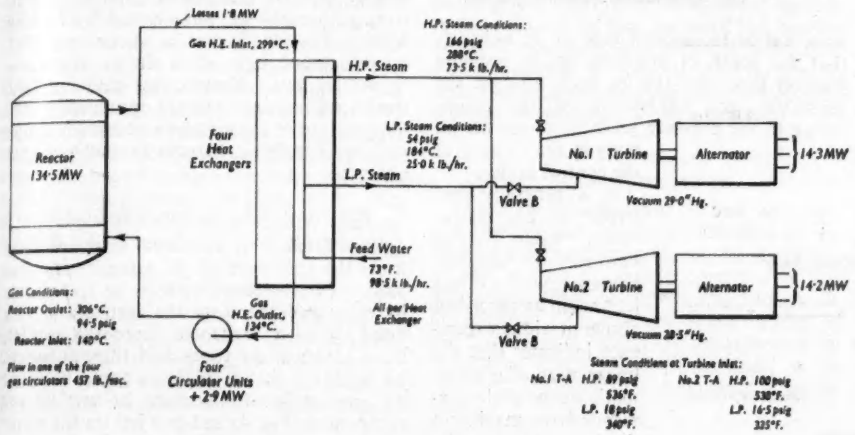


Fig. 13—Heat balance of reactor, heat exchangers and turbines

Pneumatic Measurement of Turbine Shaft Displacement*

By C. A. SCOLES

This article describes an instrument developed for accurate measurements of turbine shaft displacement during running conditions of extreme severity, where the presence of heat, steam and water, together with the need for a non-tactual and remotely indicating measuring system precluded the use of normal available measuring equipment. Instead, a pneumatic gauge was devised which successfully overcame the difficulties of measuring and, at the same time, provided the necessary wide measuring range of 0·015in, a range normally considered to be beyond the scope of an open-jet system.

THE problem was put to the Laboratory by a Glasgow shipbuilding firm,† of determining the precise amount of turbine shaft lift which occurred when a turbine was accelerated progressively from rest to maximum speed. The lift was to be measured in terms of the relative movement between the main bearing casing and the rotating shaft itself, allowing for the fact that considerable thermal expansion of both components would occur at different rates during the operation. In addition, the site of measurement would be subject to the presence of hot wet steam escaping from the main stator casing and, in any case, would be very inaccessible due to the compact design of the machine and the obstructions caused by its associated pipework, all at a high temperature.

Measuring Requirements

It was necessary, therefore, to evolve a form of measurement capable of indicating a movement as small as 0·0002in and having an overall range of about 0·015in in order to accommodate likely thermal dimensional changes additional to the changes due to the shaft lift itself. The method had to be a non-tactual one, so that the abrading action of the rotating shaft would have no deleterious effect on its long-term behaviour, and, in addition, would have to be unaffected by heat, steam and water, and be capable of providing a remote indication of the dimensional changes to which it would be subjected.

* Communication from the Mechanical Engineering Research Laboratory, East Kilbride.

† Alexander Stephen and Sons, Ltd., Linthouse, Glasgow.

Design of Instrument

For simplicity and cheapness it was considered that these requirements could best be met by an open jet pneumatic gauge, where a small jet unit would be the only part to be located in the restricted space available for the measurements. The rest of the equipment, housed in a small cabinet, could then be placed some yards away from the turbine in more congenial surroundings and connected with the jet unit by a flexible tube. This technique is similar in principle to that suggested by Guy‡ in 1922 for measuring axial displacement of turbine shafts using oil as the working medium.

Due to the rather large working range of the unit (0·015in) it was necessary to use a very large jet orifice of approximately $\frac{1}{16}$in diameter. Two different circuit arrangements were tried out with this jet, the first (Fig. 1) being one in which the control orifice was located within the cabinet—that is, at a distance of some 8ft from the measuring jet. With this system it was found that the small line resistance of the tubing connecting the two orifices was of significance, in that a change in the length of the tube affected the calibration of the gauge. In view of this, the complete instrument was calibrated using a certain length of tubing to connect the measuring jet to the cabinet, and it was essential that no subsequent alteration was made to this length.

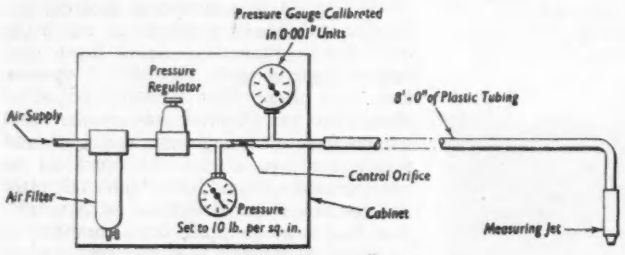


Fig. 1—First pneumatic gauging system

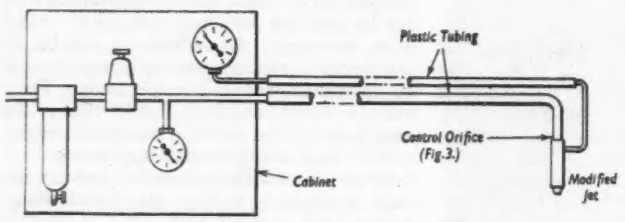


Fig. 2—Second pneumatic gauging system

The second system was adopted later when it was considered that the self-cooling action of the measuring jet and air tubing might not be sufficient in cases where turbines were operated under steam temperature conditions approaching 800 deg. Fah. The normal calibration of an air gauge remains constant only if the air between control jet and measuring jet is subject to adiabatic changes, and this would not be the case if the measuring jet were to be placed in close proximity to a very hot turbine whilst the control orifice remained at room temperature at some distance from the source of heat. For this reason the system shown in Fig. 2 was adopted. The brass jet unit was modified to enable the control jet to be located within the brass body of the measuring jet, so that in service both orifices would be subjected to the same heating effects. A small diameter pressure pick-off pipe was soldered into the flank of the jet body and connected to the calibrated gauge (Fig. 3). Two tubes were thus needed to connect the jet unit to the cabinet, but the system, apart from being largely insensitive to temperature effects, also had an improved speed of response. A point of interest noticed during the construction of the second type of jet unit was that the depth of insertion of the pressure pick-off pipe into the jet body affected the sensitivity and calibration of the gauge, owing to the pressure gradient across the jet body in the vicinity of the control orifice.

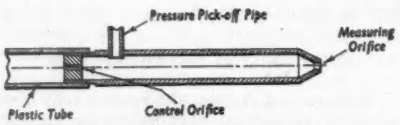


Fig. 3—Modified measuring jet unit

It is generally preferred to use instruments with linear scales, if possible. However, with a direct jet system as described above previous experience indicates that the linear part of a pneumatic gauge scale corresponds to a maximum displacement at the measuring jet of approximately 0·003in, which provides a pressure change between control orifice and measuring jet of about 50 per cent of the supply pressure§ (i.e. from about 0·4 to 0·9 times the supply pressure). In order to increase the range it is necessary, therefore, to work on the non-linear part of the characteristic curve relating back-pressure and displacement. It was found experimentally that, with a supply pressure of 10 lb per square inch, a gauge pressure change from about 2 lb to 4½ lb per square inch corresponded to a displacement at the measuring jet of 0·015in. A pressure gauge of 0 lb to 5 lb per square inch range was used to increase the sensitivity of the system, care being taken to ensure that the measuring jet was never closed completely to avoid overloading this pressure gauge.

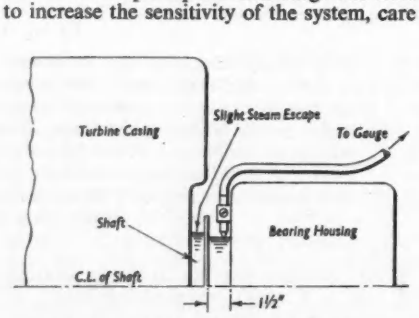


Fig. 4—Showing location of jet on turbine

Calibration of Instrument

A steel disc having approximately the same diameter as the turbine shaft was ground to a high degree of roundness and surface finish and mounted on a true mandrel in a precision, high-speed toolmaker's lathe, the final run-out of the disc being less than 0·0001in. The brass jet unit was then mounted in the toolpost of the lathe and adjusted to bear squarely on the flank of the disc at its centreline height. Controlled 0·001in feed-ins of the jet unit were then made in order to calibrate a plain dial fitted to the pressure gauge, and subsequent repeat calibrations made with the disc rotating slowly and then at speeds up to 2200 r.p.m. revealed no discernible change from the initial readings. It was thus proved that no "windage" effects resulted from the motion of the disc over this speed range. Insensitivity of the modified jet system to temperature change was verified by heating with a Bunsen burner a short length of copper tubing inserted in the air line close to the jet unit. Despite this rather drastic treatment, which raised appreciably the temperature of the air passing through the jet unit, no significant changes in readings were observed.

Practical Use of the Instrument

Shop Trials.—In the actual shipyard shop trials the first type of jet arrangement was used. Two turbines were to be tested side by side, and therefore the instrument was fitted with a switched three-way outlet, three identical air tubes and three identical jet heads, so that a single jet could be fitted on one turbine to measure its vertical lift component (Fig. 4) and two jets on the other turbine to measure both horizontal and vertical components of its rotor shaft displacement. Readings from any jet could be taken at will by merely resetting the three-way air switch. In order to allow for the thermal expansion effects, the jets were attached to the "cold" turbines and adjusted in turn to read zero on the recalibrated pressure gauge. During the warming-up period of the turbines with their shafts turning very slowly zero changes were observed. Once the turbines were up to temperature and the main steam turned on measurements were taken progressively against turbine shaft speed, and at the end of the trials the gauge readings were noted at the instant the shafts came to rest, thus establishing true zeros for the three sources of measurement, with the metal of the turbines still at its full running temperature and the shafts "dropped" in their white metal bearings.

During the trials it was noted that the jet units and the plastic tubing in the live steam area were dripping with condensed steam, yet were only slightly warm to the touch, thus indicating the efficiency of the natural cooling action of the large air flow through them. The temperature of the steam used during these shop trials was not, however, very high.

Sea Trials.—The sea trials were carried out some months later, and since it was known that the degree of steam superheat to be used at sea was considerable, the modified jet units were constructed to overcome the expected high temperature difficulties. Measurements at sea were restricted to one turbine, provision being made for using one vertical jet and one horizontal jet, each connected to its own calibrated pressure gauge. In this way, the need to switch continually from one jet to the other for the purposes of taking readings of lift was avoided.

Measurements were taken at sea during two separate full-day trials of the ship and it was observed on both occasions that various progressive changes in apparent lift occurred during the hours the turbine was running, which were obviously due to differential expansion changes between the turbine shaft and the bearing housing. Unfortunately, it was not feasible to stop

‡ British Patent No. 202,691 (1922).

§ The Engineer, 192 (4981), 62-64, July 13, 1951.

the turbine frequently in order to establish zero lift readings at the various thermal conditions applying, and hence the results obtained were not as useful as had been expected.

It had been supposed that, to a large extent, the turbine would have settled down more or less to steady thermal conditions once it had been running for an hour or so, but in fact it appeared that the relative dimensions of the shaft and bearing changed fairly quickly in accordance with the power output of the turbine at any given time.

During the second sea trial the plastic air tube supplying the horizontal jet melted with the heat, close to the jet body, where it had to lie near to the hot bearing housing. This trouble could be avoided by using copper tubing on the jet unit, coupled to plastic tubing further away from the bearing. It was noted during pronounced rolling of the ship that a rise and fall of the turbine shaft of about 0·0005in occurred at the roll frequency.

Conclusions

It would appear that this method of measurement, applied under shop trial conditions, which is simple and inexpensive to provide, forms a satisfactory answer to the general problem of turbine shaft attitude determination under adverse running conditions.

The same method could be equally successful at sea providing that the turbine could be stopped occasionally, especially at the start and finish of any full-power runs, in order to establish zero lift readings.

No provision of extra measuring stations on the turbine can overcome this requirement.

The method is not suitable for measuring dynamic eccentricity (due to transitional warping, &c.) nor critical vibration of turbine shafts owing to its time response lag, but for steady displacement measurement under suitable conditions, this feature is of no significance, and the results obtained are more than sufficiently accurate for the purpose.

Acknowledgments

The work described was carried out in the Mechanisms and Metrology Division of the Mechanical Engineering ResearchLaboratory as part of the research programme of the Mechanical Engineering Research Board. It is published by permission of the director of the Laboratory. The facilities provided by Alexander Stephen and Sons, Ltd., at its shipyards and at sea are gratefully acknowledged.

Iron and Steel Institute

AUTUMN MEETING

No. I

THE autumn meeting of the Iron and Steel Institute was held, in London, on Wednesday and Thursday, November 21 and 22, the president, Dr. H. H. Burton, occupying the chair. The official business of the Institute, which was transacted on Wednesday morning, included the nomination of next year's president. A resolution was unanimously carried for the nomination of Mr. Arnold H. Ingen Housz, of the Royal Netherlands Steel Works, who has been an honorary vice-president for several years. Dr. Burton, in moving the resolution, said that only rarely did the Institute elect as president a member from outside Great Britain, the last occasion being nearly forty years ago. The nomination of Mr. Ingen Housz was in keeping with the international "colouring" which was such an important factor in the life and work of the Institute.

After dispatching the official business the meeting turned to the discussion of a series of technical papers. The first four of these were considered together :

RECORDING TECHNIQUES FOR ROLLING MILL OPERATION STUDIES

By E. A. Chard, B.Sc.(Eng.), W. W. Hastings, B.A.Sc., and D. F. Nettell, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E.

Synopsis

Previous studies on rolling mills have depended on the participation of a number of observers. In order to eliminate human errors and to provide a continuous record, the techniques described in this paper have been developed.

The two instruments used, a modified teleprinter perforator and a twelve-channel recording oscillograph, are complementary in their application and the use of one or the other in a particular application is governed by the information required. Some tests carried out with the twelve-channel recorder, at a works, are discussed.

THE TIME CHARACTERISTICS OF THE SLABBING MILL

By H. G. Jones, D. T. Steer, and P. D. Dickerson

Synopsis

The object of breaking down the rolling process into functional components is to enable the time to be synthesised for the rolling of any ingot to any slab section.

Numerical values of the constant and variable time components of the rolling of a slab are quoted and their importance discussed. The synthesis of the components is illustrated for a particular case and the general validity of the synthesis is checked by reference to a detailed study of three shifts.

The effects of the speed of the work rolls of the mill and of deeper draughting on the output of the mill are also discussed.

NOTE ON THE PRINCIPLES GOVERNING THE DESIGN OF INGOTS FOR HIGH OUTPUT IN THE SLABBING MILL

By H. G. Jones, P. D. Dickerson, and D. T. Steer

Synopsis

It is shown that the output from a slabbing mill producing a given range of slabs can be increased by using thicker ingots. The width of the ingots has virtually no effect on the tonnage rolled, provided that no extra tilts are involved. Increase in height of the ingot (particularly at the expense of the width) also increases output.

MAXIMUM UTILISATION AND PROBLEMS OF WIDE-STRIP ROLLING AND SHEET FINISHING EQUIPMENT

By H. H. Ascough, M.I.Mech.E.

Synopsis

The paper describes the system of operating the 45in slabbing mill and 80in hot and cold strip mills of The Steel Company of Wales, and includes detailed operating data. Significant factors influencing productivity are commented upon in relation to the future design of similar installations.

Discussion

Mr. N. C. Lake (Head, Wrightson Machine Company, Ltd.) : There was, I think, in Mr. Ascough's paper a very timely reminder to those of us who are plant makers that after we have done our best, or our worst, there still remains the very considerable management problem of controlling the flow of materials in such a way as to ensure that all the equipment we have provided is utilised properly and to its maximum efficiency. I found the charts on the organisation and the control of the Abbey Works to be of great interest. I should be interested to learn whether, as a result of the investigations which have been taking place, consideration has been given to the application of automatic position control on the slabbing mill. It would seem evident from what we have been told that an increase in the rolling speed would not necessarily give an increase in output commensurate with the added power consumption and the added wear and tear upon the parts, but it would seem evident to me that there is a considerable improvement available to us by reducing the time that the mill is not actually rolling, possibly a reduction in the time of manipulation of reversing of tables and of the setting of the screwdown. I did see a little while ago a billet mill which was controlled practically automatically with the positions predetermined.

There is a reference in Mr. Ascough's paper to the possible use of load meters on the hot mill coupled to the screwdown as a means of controlling gauge and reducing differential in thickness from end to end of a strip. I would be interested to know whether provision is being made in those arrangements to deal with the temperature difference, because it would seem to me that the temperature difference will give a differential rolling load, and this will therefore need overcompensation in order to make the strip to the right gauge, even though it is colder at the tail-end. There is the factor of spring in the housing which would arise from the colder material. I was interested to notice the design of the coilers. Many years ago I had a lot to do with putting in what was the first strip mill in this country on brass and copper, and we had a coiler of somewhat similar design. We were troubled with the shrinkage on the outer laps upon the inner nuts which caused relative movement and pick-up. That seems to be something which the steel people do not suffer from, and I wonder whether when you are coiling this heavier gauge material which is now contemplated you will not get a greater tendency for the coil to shrink and therefore impose higher loads upon the mandrel.

I have a great interest in this problem of cut-up lines, and the debate between the merits of high-speed and low-speed cut-up lines goes on in many directions. I was glad to hear that Mr. Ascough favours a balanced plant as high-speed and low-speed lines. I have at times doubted the merits of high-speed lines for a jobbing business such as we seem to have in this country. It seems that with orders of 100 or 200 tons magnitude a high-speed line might be running at high speed for 20 seconds and idle for another 10 to 20 seconds while separating passes are put between the packs if you have a single piler. If you have a double piler, you can operate the line at high speed for most of the time. I made some calculations a little while ago and I found that the time on a high-speed line running nominally at 1000ft per minute, but actually at 800ft per minute doing a coil of 50,000 lb, allowing for stoppages for each unpack, would be about 10 minutes, whereas with a two-pile arrangement which enables the line to run continuously the time would be about five minutes on a 50,000 lb coil. If we ally that to the wear and tear upon the moving parts which have to be accelerated and decelerated, say, twelve times per coil, it would seem that we have a case for either doubling up the pilers on these lines so as to enable them to run for high speeds most of the time, or, alternatively, for putting in some low-speed lines for the smaller orders.

Mr. W. H. Schofield (Richard Thomas and Baldwins, Ltd.) : In July and August of this year we carried out similar investigations on a 44in slabbing mill with the same object in mind, i.e. to determine the ultimate output which could be anticipated from the mill. As a result of this test, we have various interesting comparisons to make. The tests which we carried out were less extensive than those described in the paper on " The Time Characteristics of the Slabbing Mill," and in fact the timing of the rolling sequence was obtained from the mill motor current and revolutions per minute curves which were recorded. Although curves and equations were not evolved for the time in the rolls, several of the figures have been checked which bear out these equations approximately if account is taken of the difference in basic speed of the two mills of 40 and 50 r.p.m. respectively. The time between the passes was about double those recorded in the paper, but we feel that this is due mainly to difference in screwdown speeds and probably to the method of control of the screwdown motors. The times out of rolls for both down-tilt and up-tilt were about 30 per cent greater than in the paper, this again being probably due to the screwdown speed and method of control. The time between ingots was slightly less than those given in the paper, but as our test was carried out over a much more limited period, we feel that there is little conclusion to be gained from this particular factor, as our results were rather scattered. The method of establishing the time characteristics was basically the same, differing only in the method of recording the data and in the actual characteristics evolved.

I feel that a conclusion which can be drawn from the results of both tests is that increase in screwdown speed and improved control would decrease time between passes which were non-tilting, but that the time between passes when tilting takes place is governed mainly by manipulation time. This latter point is borne out by the fact that both tests show longer times for up-tilt than for down-tilt operations. It is stated that a universal mill would decrease the time per ingot by 11 per cent because of the fact that two passes per ingot and tilting would be eliminated. I should have thought that at least the second and third sets of edging passes would be eliminated completely in that they would be carried out at the same time as the flat passes. Our forecast for the range of ingots being considered, averaging 9·5 tons, was that a universal mill would increase output by approximately 50 per cent. It may be that the 11 per cent figure which has been given bears relation to improvement on tandem rolling, which is something that we were not considering at the time. After we had tried very heavy drafting up to 3in it was decided that the heaviest draft which could be readily taken was 2in on flat passes on the barrel, as any increase in this figure caused entering difficulties which countered the improvement achieved by reduction in number of passes. This conclusion is in agreement with that given in the paper. We found that the draft could be exceeded when edging in the grooves, as the side friction assisted in entering the slab, and we did in fact get up to 3in reasonably on edging groove passes.

When referring to the effect of increase in speed, the paper says that any increase in speed raises the question whether sufficient horsepower is available. I wonder whether this was ever obvious as a limitation. The most critical horsepower requirement that we can see would be corresponding to a 2in draft on a 60in wide slab when reducing probably from 8in to 6in, and we wonder whether any limitation was obvious on the mill and what horsepower was in fact used for a reduction of this kind. One of the conclusions drawn following our test was that improvement in screwdown control was the main factor which could improve existing mill output, possibly with the adoption of automatic screwdown scheduling, which was referred to by Mr. Lake.

Mr. Veldhuis (Royal Netherlands Steel Company) : Two questions arise in regard to the time during which the authors were taking readings. First, did they take into consideration whether the crews differed in any significant way in the manner in which they handled the ingots ? We found that this was something that had to be taken into account. Secondly, because the time during which they took the readings was so short, the influence of the diameter of the roll might be quite big, having regard to the fact that the readings taken were extrapolated. I assume that the roll diameter was 45in and that it would vary about 2in. When the time of reading was 47 or 43, it would be just a coincidence that the checking up of output numbers was the same as had actually been forecast. Next, the authors have discussed in detail the influence of speed. I wonder whether they consider that any gain could be had from some solution of the speed variation. I think that the top speed is hardly ever realised in a mill with the slab sizes that the authors mention, but on acceleration it may be much more important. I think that the mill hardly does anything else but accelerate and decelerate. It is quite possible that there may be a gain there.

Dr. L. N. Bramley (B.I.S.R.A.) : I should like to draw a comparison between the steel industry and the aircraft industry which I came from before I joined B.I.S.R.A. in 1946. If I go into a steel mill now and walk through a melting shop, I can see rows and rows of beautiful recorders and instruments. The whole place is very well instrumented indeed. But if I go into your research departments or development departments and ask to see the oscillography equipment, I am afraid that I am due for a disappointment, because very few of you have any adequate equipment at all.

The first paper describes the tape perforator, which is a digital instrument, and the twelve-channel recorder, which is an analogue instrument which will record continuously varying quantities, and a digital one set quantities. You have plenty of ordinary tape recording equipment for the routine production jobs, but there must be many times when the engineers and the production men want to go into the plant and get data on an experimental basis, and I must say that the industry is very badly instrumented for this purpose. I am going to give you one or two comparisons. In the paper there is described a twelve-channel oscillograph. It is an extremely versatile instrument. B.I.S.R.A. authorised the expenditure, and I managed to get it about two years ago. Ever since we have had it, it has been in almost constant use. It can measure anything from 5000A up to 6000V, on motion, pressure, velocity—anything you like. It is a standard instrument and it is easily used. When taken out into the plant, it can be put to work in all twelve channels in a very short time. And yet the industry as a whole in this country, with a turnover of £800 to £1000 million, has got one of these instruments. The Royal Aircraft Establishment has either got or has on order eighty of those same instruments. I cannot believe that the need of the steel industry is really expressed in that proportion.

Since this paper was written, two developments have taken place. As you know, the tape perforator, which is a very versatile instrument developed by B.I.S.R.A., is described in the paper as printing up to ten characters a second ; but now, as a result of our work, we have managed to get the Creed Company to develop a new instrument which is giving twenty-five to thirty perforations a second, and that means that digital techniques in the steel industry can be matched very much more to your needs, and we can do very much better. The first instrument was very slow, and now the fast one has come about purely as a result of our development work in B.I.S.R.A. It is now readily available as a standard instrument. Another instrument is the new six-pen recorder, which has been developed. The twelve-channel recorder that I have been talking about has got the disadvantage that you have to make the exposures on photographic film, and that means that it must be either developed on site or developed later on in the dark-room. There is a developer which you can have at your side, and you can put the film straight into it and get the thing out. But it is better to be able to see what is being recorded at the time. I have here a chart which shows the sort of thing that you can get now off a new instrument available in this country with six separate pens. It has a response of up to 65 c/s, which is all we are going to need for the vast amount of experimental technology which is needed in the steel plants.

Another important development which is taking place within B.I.S.R.A. now on this question of experimental instrumentation is the development of an analogue-to-digital converter and other equipment which will take in a digital signal and give out an analogue signal. We have not yet got anything that can be used immediately, but we have already made some progress, and notably last year, at The Steel Company of Wales, we were able to produce a rough form of analogue-to-digital converter which took in a signal from a Taylor Hobson gauge and produced a perforated tape record—but that is only a beginning. As soon as we can produce better analogue-to-digital converters it will mean that the dream that I have had for many years of getting all the data in the steel works on perforated tape and thus making available a far higher factor of analysis will become true. I think we ought to drop the term " teleprinter technique." We are not using teleprinters ; we are using tape perforators, and I do not think that the word " teleprinter " is at all apposite.

In introducing his paper, Mr. Ascough showed a slide containing a list of breadths and widths of rolled ingots, and the slide showed some half-a-dozen dimensions going down in steps of 2in. Then there was a break and it went over to slab to edge or edge to slab, and then when it came back to slab again there was not a step down, but it was back again to the last finishing dimension. I will give an example : it was 56, 54, 52, 50, 48, and then it went over to slab and then came back again, and it did not start at 46 but at 48, indicating that there had been some spread in the ingot. I had always been under the impression that the spread could be so high that we would have to roll at a higher figure the first time on slab after edge passing than we had as the final slab rolling dimension.

(To be continued.)

Notable Locomotives of 1906

By E. C. POULTNEY, O.B.E.

No. II—(*Concluded from page* 733, *November* 23)

Hughes' Compound Freight Engine

The Hughes' compound of 1906 was a standard 0–8–0 freight engine having a pair of inside cylinders, 20in by 26in., and 53½in coupled wheels, which was converted to compound expansion by replacing the existing cylinders by a pair, 22in by 26in, for the l.p. cylinders and adding two h.p. cylinders, 15½in by 26in, outside, in line with the middle pair. All cylinders drove through the second coupled wheels, the inside l.p. pair by means of a built-up crank axle and the outer h.p. cylinders through crank pins in the wheel centres. The adjacent h.p. and l.p. cranks were placed on opposite centres and the h.p. cylinders drove through the third pair of coupled wheels.

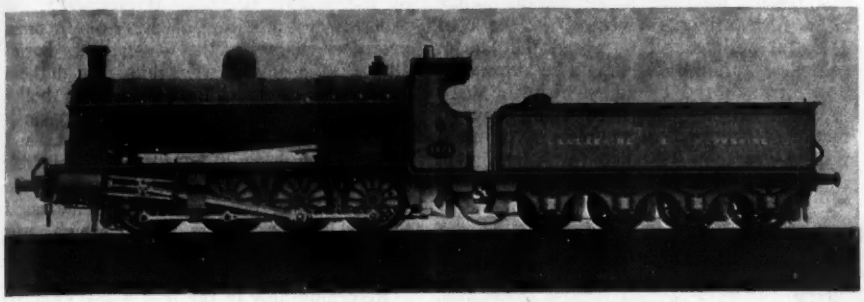


Fig. 5—Hughes' compound freight engine, L. and Y. Railway

each pair was at right angles to the other. Joy's valve gear, standard on the L. and Y., operated the valves, one set of gear being used for each pair of h.p. and l.p. valves. The h.p. cylinders had inside admission piston valves and the l.p. balanced slide valves with open backs, thus allowing the exhaust steam to pass direct to the blast pipe.

Rocking shafts connected the inside valve gear to the spindles of the piston valves and, as these gave inside admission, the arrangement was such that the h.p. and l.p. valves worked in the same direction. Starting was effected by two sliding valves placed back to back and fitted in a chamber in the l.p. cylinder casting. This chamber was connected to the main steam pipe in the smokebox and, when the engine was in either full forward or full back gear, the sliding valve, operated by a connection with the reversing gear, allowed boiler steam to enter the l.p. steam chests direct when the main regulator valve was opened. When the engine had started and after the valve gear had been adjusted to reduce the rate of cut-off to about 70 per cent the starting valve shut off the boiler steam supply to the l.p. cylinders and the engine then worked as a compound. With this simple arrangement for supplying steam to the l.p. cylinders to facilitate starting the steam acted as back pressure on the h.p. pistons, which, it will be understood, were only more or less in equilibrium ; it was nevertheless found quite satisfactory in practice, being assisted by the large diameter of the l.p. cylinders.

Both the simple and compound expansion locomotives had the same working steam pressure of 180 lb per square inch. The illustration (Fig. 5) shows these compound engines as subsequently built, and the dimensions as given in the table refer to these later engines, which, it will be noted, differed from the single experimental engine of 1906 by having a divided drive ; that is to say, W. M. Smith's system, all driving the leading coupled wheels, the inside l.p. pair through the medium of a crank axle and the outside h.p. cylinders through crankpins in the wheel centres. All four cylinders had piston valves and one engine was fitted with two sets of Stephenson's valve gear and the other with two sets of Walschaerts gear. The valve gears were inside the frames so that the l.p. valves were driven direct and those for the outside h.p. cylinders were operated by rocking levers connecting the inside valve gears with the valve spindles for the outside valves, an arrangement made possible because adjacent h.p. and l.p. cranks were on opposite centres and each pair at 90 deg. to the other. W. M. Smith's starting valves were fitted, and also the pressure equalising connections fitted with non-return valves between the h.p. and l.p. cylinders associated with this system of compounding. The boilers of the Belpaire pattern were an innovation in North Eastern practice and, moreover, carried a higher working pressure than had hitherto been used on this railway.

In respect to the use of Walschaerts valve gear, Belpaire type boilers and four cylinders, these are the only locomotives ever built for the North Eastern embracing these features. However, they are generally understood to have done very satisfactory work when operating fast passenger services, and one of them worked experimentally for a time on the North British Railway between Carlisle and Edinburgh (Waverley). From the table of dimensions, it will be noted that the cylinders were very similar in size to those used for the Horwich compounds, the only difference being in the diameter of the h.p. cylinders, which, for the N.E.R. engine, were 14½in, comparing with 15½in diameter for the Hughes' compounds.

North Eastern Railway

Two locomotives, intended for fast passenger traffic, of an entirely new design were built at Gateshead in 1906, which would seem to have been experimental, being in many respects very different from previous North Eastern practice. As the illustration (Fig. 6) shows, the 4–4–2 wheel arrangement was used, being in this respect like Worsdell's large class V "Atlantics" of 1903, but, in place of two cylinders only, the new engines had four, compounded on

Great Western Railway

While the application of the Schmidt superheater to the engine "Lady Superior" marked an event of first importance, the year 1906 will undoubtedly also be remembered as that which saw the completion of G. J. Churchward's first four-cylinder express locomotive No. 40, "North Star."

Before, however, dealing with this outstanding development, it will be desirable to refer back to the introduction in 1903 of the French four-cylinder compound No. 102, "La France," and to the further two larger compounds, Nos. 103 and 104, "President" and "Alliance," placed in traffic during 1905. With the arrival of "La France," Churchward converted his own 4–6–0 engine "Albion" to one of the "Atlantic" 4–4–2 type to match in wheel arrangement the French-built engine, and followed this by designing a further engine, also of the 4–4–2 type, which, instead of having two cylinders, was fitted with four, arranged rather like those of the French-built compounds except that the inside pair, instead of being directly under the smokebox, were placed further forward and combined in their casting a saddle portion upon which part of the smokebox rested. The idea of adopting this cylinder arrangement seems to have been to obtain connecting-rods for the outside and inside cylinders of the same lengths, which actually were 8ft and 7ft 10in respectively. The photograph of this new engine shows that the position of the outside cylinders was substantially the same as for the French compound engines already illustrated in previous articles in The Engineer of August 21, 1953, and August 12, 1955.

From the foregoing description of this locomotive, it would rather seem that its design was to some extent suggested by the

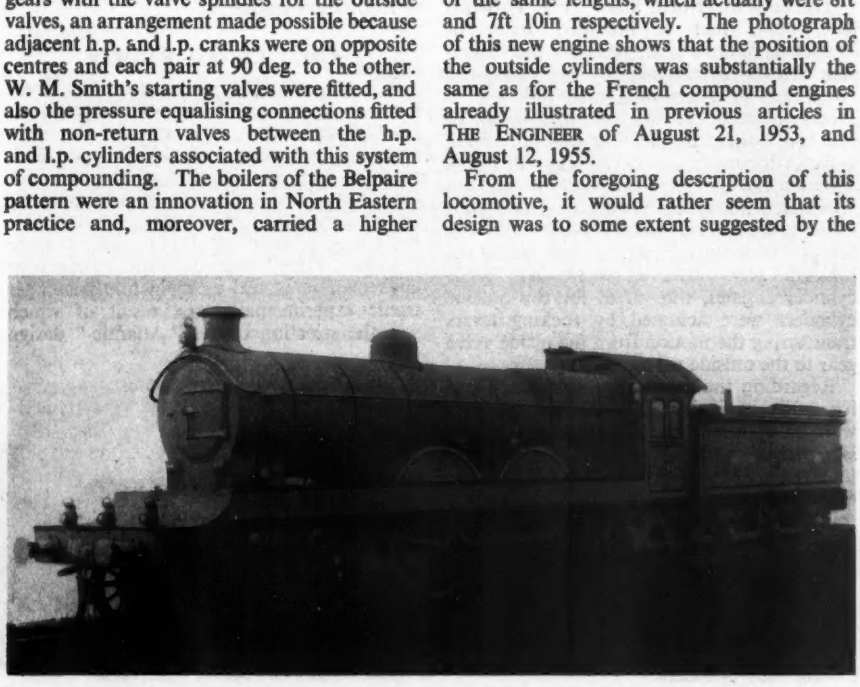


Fig. 6—Compound express passenger locomotive, N.E.R.; Wilson Worsdell

French engines; it was not, however, a compound, all four cylinders, each 14½in by 26in, taking steam at a pressure of 225 lb per square inch from the boiler. These dimensions, in conjunction with 80½in driving wheels, provided a maximum tractive effort of no less than 25,200 lb, a very high figure for a four-coupled engine; in fact, far in advance of any other ever built with only 39·6 tons available for adhesion, giving an adhesive factor of only 3·52. This engine had the standard Swindon No. 1 boiler of the same general dimensions as used for the previously built 4–4–2 and 4–6–0 two-cylinder locomotives, but modified by having a continuously tapered barrel in place of the former plan of restricting the tapered portion to that part adjacent to the firebox.

The cylinders were carefully designed with respect to clearance volume, in line with previous practice and had 8in piston valves: the ports in the valve bushes measured 25in by 1·5in, so that, making allowance for the bridges in the ports, the actual area through the bushes would be about 25 square inches, equal to, say, 15 per cent of the piston area. What the area of the ports between the valve bushings and the cylinder was the writer does not know, and though this dimension is definitely important, it is nevertheless equally important to remember that it is the area through the valve bushes that varies with valve travel and hence the rate of admission per cent.

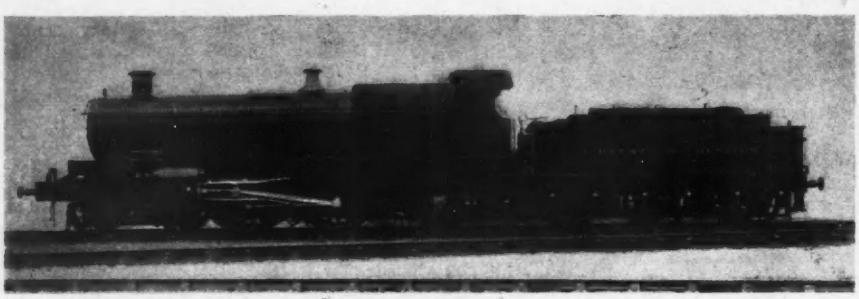


Fig. 7—Churchward's four-cylinder express passenger locomotive "North Star" for the G.W.R.

The engine "North Star" (Fig. 7), when first built, had a modified form of Walschaerts valve gear, whereby the expansion links were actuated by the piston-rod crossheads by means of suitable linkage, the arrangement being that the crosshead of one rod worked the link for controlling the valve of the other cylinder. While this plan obviated the need for eccentrics, it was not considered altogether satisfactory, and later engines were fitted with a more orthodox form of Walschaerts gear. In the case of the "North Star" and all subsequent four-cylinder engines, the valves for the outside cylinders were actuated by rocking levers transferring the motion from the inside valve gear to the outside valves.

Regarding the crank arrangements, those for adjacent inside and outside cylinders were on opposite centres, and the right-hand side pair of cranks led the left-hand side pair by 90 deg. Mention should be made of the fact that the valve gear imparted a maximum travel of 7in to the valves, which were set to give a constant lead of ¼in. This setting seems to have been later modified to give a $\frac{3}{16}$in lead, the steam lap being 1⅛in and the full gear travel 6⅞in. It is thought these dimensions apply to later 4–6–0 engines, of what became known as the "Star" class, having four cylinders.

This celebrated engine, "North Star," perhaps one of the most notable passenger engines ever built, was an outstanding success and, as events over the years have abundantly shown, proved to be the forerunner of a long line of remarkable engines of which more may be said on a future occasion. In the meantime it may be remarked that this locomotive has received a somewhat extended notice for the simple reason that it merits it, being the work of a skilful designer who realised that steam generated by the boiler should be allowed to flow through the cylinders with the least possible obstruction other than that imposed by the effort exerted on the pistons. Churchward went some distance towards solving this problem, which is still one of those requiring a little energetic action on the part of locomotive engineers.

Fig. 8—Six-coupled express passenger engine for the G.C.R.; J. G. Robinson

Great Central Railway

For fast passenger services on the Great Central, John G. Robinson designed at Gorton and Beyer, Peacock and Co. constructed ten six-coupled 4–6–0 type locomotives (Fig. 8), the first of the type for this class of traffic since the two supplied by the same firm to Robinson's design in 1903; he, it may be recalled, also built at the same time two of the "Atlantic" type. These four engines were placed in main line passenger traffic experimentally, the result of which was the selection of the "Atlantic" design as being the more suitable for requirements. Between 1903 and 1906, including eight engines built by the railway company in the latter year, a total of twenty-seven "Atlantics" of Robinson's standard two-cylinder design were turned into traffic, which, together with four compound "Atlantics" (Smith's three-cylinder system), constructed by the railway company during 1905 and 1906, made up a total of thirty-one express passenger engines of the 4–4–2 type. Basically, all these engines were alike, though there were some slight differences in the boiler heating surfaces, due, apparently, to small variations in the tube arrangement, and twelve engines built by the North British Locomotive Company in 1905 had the standard boiler pressure of 180 lb increased to 200 lb per square inch, which was the same as used for the compound engines.

Returning now to the new 4–6–0 engines, these had outside cylinders, the drive being taken by the intermediate pair of coupled wheels, as will be seen from the illustration. Generally the design followed very closely that of the two experimental engines of 1903; in fact, the boilers were identical, the only notable differences being in the diameter of the coupled wheels, which was 78in, comparing with the larger dimension of 81in originally used. The cylinder dimensions were 19½in by 26in, being the larger of the two sizes fitted as an experiment * A further difference was the increased boiler steam pressure, raised from 180 lb to 200 lb per square inch. In harmony with Robinson's standards, these engines had Stephenson's valve gear operating slide valves in inside steam chests. The valves were of the balanced type. These ten engines and the two built in 1903 were the only examples of the two-cylinder 4–6–0 type with outside cylinders designed by J. G. Robinson for passenger service, and, in fact, were the only six-coupled engines used for this service till 1912. From then on much larger 4–6–0 engines, but with two inside cylinders, were turned out from the Gorton Works.

* Of the two engines built experimentally in 1903, one had 19in and the other 19½in cylinders. The Engineer, August 21, 1953.

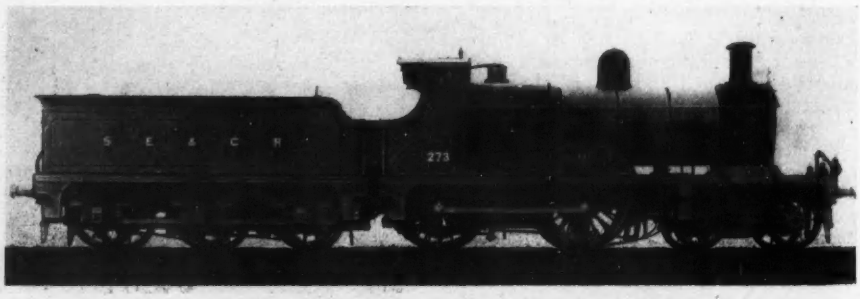


Fig. 9—Wainwright's four-coupled passenger engine for the S.E. and C.R.

South Eastern and Chatham

In common with other lines, the S.E. and C. Railway was finding it necessary in 1906 to provide engines of increased power for important passenger service, in this case more especially to work heavy Continental boat trains between London and Dover. A new class of 4–4–0 type (Fig. 9) was therefore designed by the locomotive superintendent, H. S. Wainwright, the principal feature of which was enhanced boiler capacity compared with previous practice on the line. In other respects the new engines departed little from those of the same type found on other railways at that time. Thus, the cylinders inside the frames with slide valves between, operated by Stephenson's valve gear, were in line with usual practice. The cylinders, 19½in by 26in, were, however, about the maximum diameter possible with valve chests between, on account of the small space available for the two slide valves and the difficulty of providing adequate port areas between the valve faces and the cylinders. The large cylinders, in conjunction with four coupled wheels 78in diameter and a boiler steam pressure of 180 lb per square inch, gave the engines a maximum tractive force of 18,860 lb, representing a high value for an engine of this type. However, an adhesive weight of 34·9 tons gave a factor of adhesion of 4·15, which would be ample under average rail conditions. A feature of these engines was the inclusion of a steam-operated reversing gear which had been in use on this line for some years and was due in the first instance to James Stirling, the former locomotive superintendent. The boiler designed for these engines was of the Belpaire pattern and had a total heating surface of 1523 square feet and 21·15 square feet of grate area. In respect to these dimensions, the boilers were generally similar to those used for 4–4–0 type engines on the Midland, Caledonian and other railways at that time.

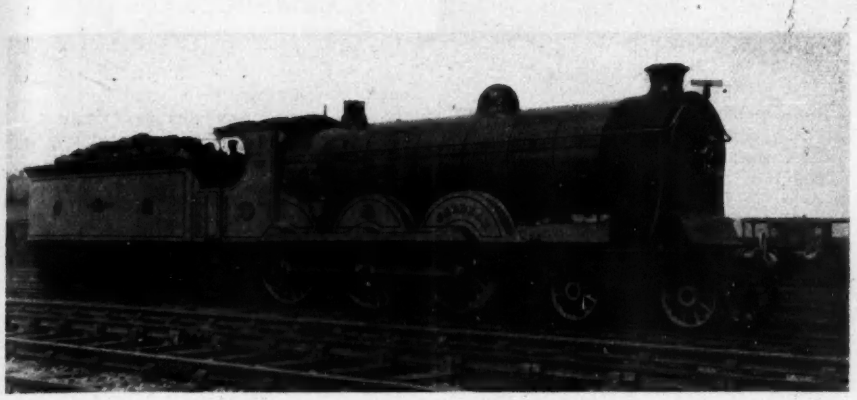


Fig. 10—Six-coupled express passenger engine "Cardean," C.R.; J. F. McIntosh

Caledonian Railway

No less than three new classes of locomotives were turned out by the St. Rollox Works of the Caledonian Railway during 1906. Designed by John F. McIntosh, they were all of the six-coupled 4–6–0 type, built for express passenger, mixed traffic, and for main line general freight requirements respectively. The dimensions of these three classes are given in the table. The first example is a large engine, five of which were constructed and known as the "Cardean" class (Fig. 10), designed specially to work the heavy West Coast joint traffic running between London (Euston) and Glasgow (Central) over the Caledonian line between Carlisle and Glasgow. These services, comprising restaurant and sleeping car trains, required powerful engines for satisfactory working, and the new design was introduced to supplement the work being done by the two large engines, also of the 4–6–0 type, Nos. 49 and 50, already in traffic, which were built in 1903. When designing the new engines, opportunity was taken to effect some improvements. For instance, direct staying was adopted for the crown of the inner firebox in place of the girder type supports formerly fitted, thus effecting an improvement by assisting materially the proper washing of the firebox crown plate. Further modifications consisted of increasing slightly the length of the connecting-rods and also increasing the length of the main crankpin bearings; thus pressures on the crosshead slides and crankpin bearing loadings were reduced, and were still further eased by reducing the diameter of the cylinders from 21in to 20in. In other respects the new engines were very like Nos. 49 and 50; that is to say, they had balanced slide valves in overhead steam chests which, in common with all Caledonian locomotives, were operated by Stephenson's valve gear. In the case of these engines, the valve chests were, as stated, above the cylinders and rockers were fitted to connect the valve gears with the valve spindles. The reduction in the size of the cylinders reduced the maximum tractive force from 24,990 lb to 22,667 lb. The new boilers, which were of generally the same dimensions as for the engines of 1903, provided a total of 2265·75 square feet of heating surface, comparing with 2323·0 square feet. The grate area of 26 square feet was the same in each case.

Before leaving these engines and passing on to the others, there is a point in their design deserving notice as illustrating a difficulty which may be encountered when two large cylinders are used and fitted inside, i.e. between the frames, as was the case with the "Cardean" class. The cylinder centres measured 24½in and the transverse distance between the centres of crank axle journals was 47¾in. These dimensions, in conjunction with the desire to provide journal bearings 9½in diameter by 10½in long, not only necessitated the wheel centres being rather considerably dished outwards, but also required the wheel seats to be made 8½in diameter, that is, 1in less than that of the journals, apparently in order to maintain sufficient metal in the wheel bosses between the wheel seat bore and the bore for the coupling rod crankpins, which measured 5in diameter. The writer does not know the throw of the coupling rod cranks, but, as it is usually desired to keep this dimension to a minimum figure, no doubt this peculiar form of crank axle was in a measure due to this consideration. That adequate main journal dimensions would be very desirable will be fully appreciated when the high piston thrusts coupled with the use of crank axles and coupling rod crankpins at 180 deg. with the corresponding inside crankpins are taken into account. Further, the point must not be overlooked that the driving torque due to the large cylinders and high steam pressure had to be transmitted through wheel seatings of reduced diameter in relation to the adjacent main journal bearings. Perhaps, in connection with the foregoing, mention may be made of an important paper on the subject of "Locomotive Axleboxes," read before the Institution of Locomotive Engineers, 1944, by E. S. Cox, British Transport Commission, when the loadings imposed on axleboxes were analysed.

The next two locomotives, Figs 11 and 12, also of the 4–6–0 type, with two cylinders, had, like the "Cardean" class, the drive taken by the leading pair. In the case of one design, the coupled wheels had a diameter of 69in to fit them for general passenger and fast freight traffic, and the other class had smaller wheels, 63in diameter, and were intended more especially for ordinary freight traffic on the main line. The mixed traffic and the freight engines had boilers of practically the same size, the main difference being that, on account of the smaller driving wheels, those for the freight engines had a rather shorter barrel section, but the fireboxes were exactly alike for both these engines.

Fig. 11—McIntosh mixed traffic engine for the C.R.

These two classes had cylinders of the same size, namely, 19in by 26in, but the mixed traffic design had slide valves in overhead steam chests and operated through the medium of rockers by Stephenson's valve gear, while the freight engines also had slide valves but in this instance arranged between the cylinders and, therefore, operated direct, again by Stephenson valve gear. The mixed traffic engines, though actually

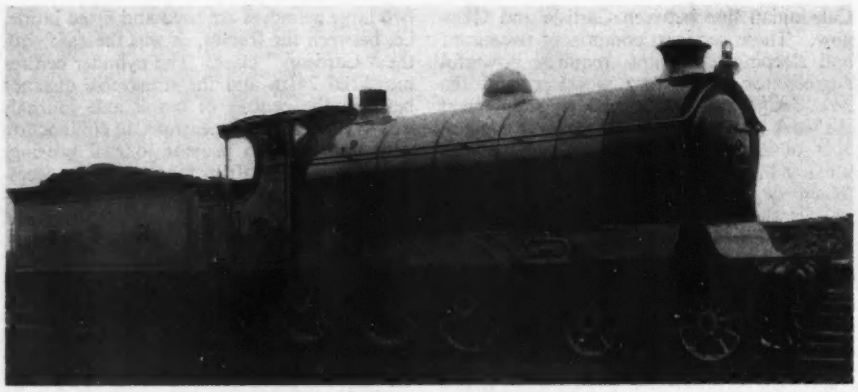


Fig. 12—McIntosh freight engine for the C.R.

intended more especially for fast main line freight services, were, in fact, extensively employed in passenger traffic, principally between Glasgow (Buchanan Street), Perth and Aberdeen, and also to some extent on the Clyde Coast train services.

North British Railway

Like the Caledonian, the North British provided the motive power for working important Anglo-Scottish passenger traffic north of the Border, and with the development of these services also found that more powerful engines were required. Unlike the Caledonian, the North British Company was called upon to find the engine power for two different and more or less competing passenger services, because, being partners with the Great Northern and North Eastern, the company was responsible for working the East Coast joint services from Berwick to Edinburgh (Waverley) and Aberdeen,† and at the same time the Midland Company's trains had to be worked over the extremely difficult road between Carlisle and Edinburgh, known as the "Waverley Route." Actually, it seems that it was the difficult nature of the traffic working over this route that was in a great measure responsible for the need for increased engine power. Hitherto, the North British had relied on four-coupled 4–4–0 type engines, which had been gradually developed by Matthew Holmes in much the same manner as by McIntosh on the Caledonian and with equally satisfactory results. However, on the retirement of Holmes in 1903 and the appointment of W. P. Reid as Locomotive Superintendent, consideration was in due time given to the introduction of much larger engines. The Great Northern and the North Eastern Railways were then conducting fast passenger trains with "Atlantic" type locomotives, and it is therefore not altogether surprising that Reid selected this design for his new engines, which were possibly considered suitable for the Waverley Route on account of the sinuous nature of this line and to the fact that an "Atlantic" might be more flexible than a 4–6–0 design. However, whatever may be the reason for the use of the "Atlantic" type, Reid designed at Cowlairs and the North British Locomotive Company built fourteen very large examples of this type for the North British line in 1906, Fig. 14, thus inaugurating the first and only 4–4–2 type passenger engines ever built for a Scottish railway.

† The North Eastern had statutory running powers over the North British line between Berwick and Edinburgh, which were exercised in the case of certain express services.

As already mentioned, the North British worked in conjunction with the North Eastern and no doubt was fully conversant with W. Worsdell's fine "Atlantics" of the Class V, first built in 1903, and if the leading dimensions of these "Atlantics" are compared with those of the Worsdell engines (The Engineer, August 21, 1953), it will at once be seen that there is a strong resemblance between these two designs.

The chief distinguishing feature was the use of a Belpaire type of boiler for the N.B. engine; otherwise they were remarkably alike. This will be seen from a brief summary of their chief dimensions, given below :—

Railway	N.B.R.	N.E.R.
Date	1906	1903
Cylinders diameter and stroke, in	20×28	20×28
Driving wheels diameter, in	81	82
Steam pressure, lb p.s.i.	200	200
Heating surfaces, square feet	2256·2	2455·8
Grate area, square feet	28·5	27·0
Engine weight, tons	74·4	72·0

The N.B. engines, like the N.E.R., had piston valves of the Smith pattern, 10in diameter, and also Stephenson valve gear. The Reid "Atlantics," with a weight of 74·4 tons, were the heaviest in the country.

A Proposed Compound "Atlantic"

Though, as already pointed out, the Reid "Atlantics" were the first and only engines of this type to be built for a railway north of the Border, they were actually not the first of this design to be suggested, because early in 1905 J. F. McIntosh at St. Rollox gave consideration to this type and prepared a design for a four-cylinder compound 4–4–2 passenger engine. A few particulars of this proposal may be of interest and are as follows. The boiler was to have been generally as for the two existing 4–6–0 passenger engines of 1903, Nos. 49 and 50, but with a larger firebox made possible by the 4–4–2 wheel arrangement. The total heating surface was 2131 square feet and the area of the grate 26 square feet.

The four cylinders were in line transversely, two h.p. outside, 15in by 26in, and two l.p. inside below the smokebox, 22in by 26in, the drive being divided, the outside pair connecting with the rear driving wheels and the inside pair driving the leading coupled wheels through the medium of a crank axle. Four sets of Walschaerts valve gear were suggested, operating slide valves for both the h.p. and l.p. cylinders. The steam pressure was to be 200 lb per square inch. The estimated weights were :—

	Tons
On driving wheels	36·5
Engine, total	72·0
Tender, full	55·0
Locomotive, total	127·0

The engine was described as being a de Glehn compound, giving a starting tractive effort of 23,250 lb and 16,400 lb working compound. This interesting proposal ended as it began—on the drawing board.

Returning now to realities and to North British developments, concurrently with the introduction of the 4–4–2 type passenger engines, a large locomotive for heavy freight traffic was also designed at Cowlairs, of which twenty were built, ten by the North British Locomotive Company and ten at the Railway Company's Cowlairs Works. Of the six-coupled 0–6–0 type (Fig. 13), these engines were notable for the considerable boiler power provided. The total heating surface was 1605 square feet with a grate area of 19·8 square feet, indicating a large boiler for engines of this type. The cylinders "inside," 18½in by 26in, had piston valves operated by Stephenson's valve gear and, in

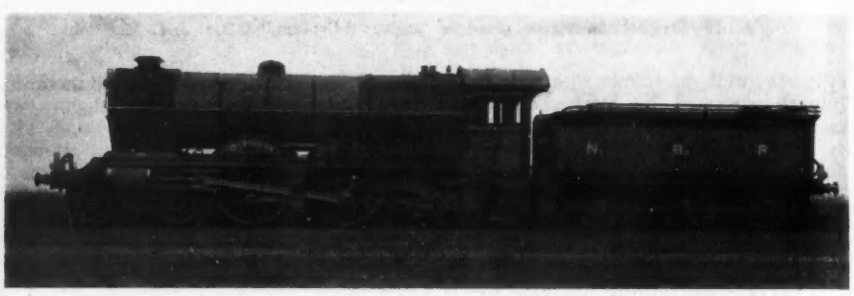


Fig. 14—Reid's "Atlantic" for passenger service on the N.B. Railway

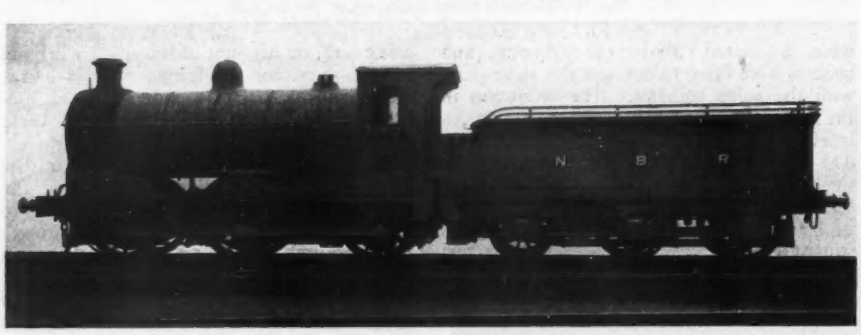


Fig. 13—Six-coupled freight engine, N.B.R.; W. P. Reid

conjunction with a steam pressure of 180 lb per square inch and driving wheels 60in diameter, gave a rated tractive force of 22,800 lb. The engine, only, weight came out at 50·35 tons, thus giving an ample factor of adhesion of 4·95.

It will be evident from the particulars given that these engines were of considerable power for handling heavy traffic at the speeds normally required, while the 60in driving wheels would make them suitable for comparatively fast running should this be required, and in this connection it may be mentioned that they were fitted with the Westinghouse air brake, which was the standard brake on the North British and also on the Caledonian.

ACKNOWLEDGMENTS

The writer is indebted to E. S. Cox, British Transport Commission, for the photograph of the Lancashire and Yorkshire six-coupled superheater engine and to the Western Region, British Railways, for making available a drawing of the Great Western locomotive, "Lady Superior." Photographs of the North British "Atlantic" and six-coupled engines have been kindly supplied by the North British Locomotive Company. The photograph of the G.C.R. six-coupled engine is from the writer's collection and was originally obtained from Beyer, Peacock and Co. The remaining illustrations are from photographs supplied by the Locomotive Publishing Company.

Technical Reports

Road Research Technical Paper No. 36, "*The Sampling and Analysis of Rolled Asphalt and Coated Macadam.*" H.M. Stationery Office. Price 3s.—Many manufacturers now control the proportions of the ingredients in asphalt or tarmacadam by analysing samples using specially devised "rapid" methods. This report outlines both the "rapid" and the British Standard methods of analysing bituminous materials and examines their accuracy. It then details the procedure necessary to obtain a representative sample.

The work shows the importance of checking, by adequate tests, that an asphalt or tarmacadam plant is producing uniform mixes; that is, that the composition, within reasonable limits, is the same in different parts of any one mix, and in different mixes. In this connection Road Note No. 21, "Tests on the Efficiency of a Twin-Shaft Paddle Mixer with Various Settings of the Paddle Tips," can be consulted with advantage. Too often small samples, sometimes only 2 oz or 3 oz in weight, are submitted for analysis and for a report on the suitability of the material they are supposed to represent. The result may be completely misleading. It is hoped that the work described here may lead to greater care being taken in this important aspect of the control of bituminous mixtures.

Saunders-Roe "Princess" Flying Boat G-ALUN Air and Water Handling Tests. Current paper No. 257. H.M. Stationery Office. Price 7s.—Tests were made at take-off weights between 225,000 lb and 315,000 lb with C.G. positions between 29 and 33 per cent s.m.c. The basic aerodynamic and hydrodynamic handling characteristics of the aircraft are satisfactory for all operating conditions tested. The limiting aft C.G. position is 35 per cent, this being imposed by the high power, low air speed conditions immediately after unsticking. In cruising flight at high altitude the limit is approximately 40 per cent. The aircraft is adequately controllable in asymmetric power conditions down to the stall, of which there is adequate warning. The artificial feel and control system gear ratios require modification to improve the feel of positive stability. On choppy seas, slight hull pounding has been encountered. The spray characteristics are satisfactory both at take-off and landing, and compare favourably with those of previous flying boats. In relatively rough water at high weight, however, fine spray caused slight bending of the tips of the inboard propellers, and a stiffened design of propeller was fitted. More flexible control of engines and propellers is desirable to improve manœuvrability on the water.

Calder Hall Reactors

No. I

A symposium on Calder Works Nuclear Power Plant was held by the British Nuclear Energy Conference in London on November 22 and 23. Some of the considerations governing the design of the reactor are given in the following article, which consists of abstracts from two of the papers discussed at the symposium—"The 1951–53 Harwell Design Study," by R. V. Moore and B. L. Goodlet, and "The Basic Design of the Reactor," by G. Packman and B. Cutts.

HARWELL DESIGN STUDY[1]

Basic Reasoning Underlying General Design.—A nuclear reactor of given design will not work unless it contains a minimum or "critical" amount of fissile material. Since fissile material is consumed at the approximate rate of 1 gramme for each MWD of heat produced, it is clear that more than the critical amount must be put in to start with. A large excess of fissile material makes the reactor difficult to control. It might, therefore, seem that the total heat output obtainable, in MWD, would be roughly equal to the initial excess of fissile material in grammes. In actual fact, with natural uranium more than this amount of heat can be drawn because some of the ^{238}U present is converted, by neutron capture, into fissile ^{239}Pu, which partly offsets the depletion of ^{235}U. If the swopping rate is such that three atoms of ^{239}Pu are created for every four atoms of ^{235}U consumed, the life of the uranium will be extended by the factor $1/(1-0{\cdot}75)=4$.

Information which became available about mid-1950 suggested that the total heat which could be drawn per metric tonne of natural uranium before the reactor ran down might exceed 2000 MWD or 48×10^6kWh.

Using the construction costs of BEPO, it was possible to estimate the capital cost of a nuclear power station and so calculate the cost of electricity generated as a function of MWD of heat extracted from each tonne of uranium. For irradiations of about 2000 MWD per tonne, and without attributing a value to the residual plutonium, it was found that the cost per unit of electricity was not greatly in excess of that from coal-fired stations. It also followed that after chemical separation, the plutonium obtained would constitute a cheap concentrated fuel for future reactors, relieved, as it would be, of the irradiation costs.[2] The design of a natural uranium power reactor was the task given to the authors by Sir John Cockcroft towards the end of 1950.

With natural uranium as fuel the only possible moderators are graphite and heavy water. Since heavy water would require dollar expenditure, and since it was thought that its theoretical advantages would, in a power reactor, be offset by many practical difficulties, graphite was chosen as the moderator. On observing that the critical diameter of the natural uranium graphite reactor BEPO exceeded 20ft and that of a power reactor would be greater, it seemed that about 30ft would be the probable diameter of the reactor core. The multiplication factor of the largest natural uranium graphite reactor could not exceed about 1·07 (with the quality of graphite then available), so the neutron balance of such reactors was delicate. It is not possible to put large amounts of neutron-absorbing metal inside the reactor core and do without enrichment. Simple calculations showed that this consideration ruled out the use, as coolants, of sodium or water carried through the core in sufficiently robust zirconium tubes. A gas, chemically compatible with graphite and therefore not having to be carried through the core in tubes, emerged as the only possible coolant.

The gas used for heat transfer has to be circulated through the reactor core channels, the heat exchangers and the connecting pipework. It is essential that the blowing power be only a small fraction of the heat power of the reactor. Only some 25 per cent of the heat can be turned into electrical energy. If the blowing power were 10 per cent of the heat power it would be 40 per cent of the electrical power generated and the net power output would be greatly reduced.

Now it can be shown that the blowing power for a heated duct at a given rate of heat removal varies roughly inversely as the square of the absolute pressure, so that at, say, 7 atmospheres the blowing power is about one-forty-ninth of what it would be at atmospheric pressure. This indicates that the gas which cools the reactor should be under pressure, i.e. that the whole reactor must be enclosed within a very large steel pressure vessel. The diameter of this pressure vessel is fixed by the critical size of the reactor at working temperature and the gas pressure is made as high as is commensurate with the difficulties of fabricating pressure vessels of this size. Remembering that drum boilers had been built of 10ft diameter for 300 lb per square inch gauge it was felt that 7 atmospheres, or 90 lb per square inch gauge, would be a possible pressure for a 30ft vessel.

In all the graphite reactors built up to 1950, the axes of the core and fuel rods had been horizontal. The design of the Windscale reactors described by Sir Christopher Hinton in his James Clayton Lecture[3] has the great merit of ease of insertion and removal of the uranium fuel elements from the core and the first thinking, therefore, visualised a Windscale type horizontal axis reactor inside a pressure vessel. This conception was, however, finally rejected because the support and restraint of the heavy graphite core from the curved surface of the pressure vessel proved an intractable problem. If a great weight inside a pressure vessel, which changes its dimensions with temperature and pressure, had to be supported, a vertical axis design seemed superior, although the insertion, support and removal of the uranium fuel elements might be more difficult.

Main Features of the Design.—In a graphite reactor of the kind considered, wasteful neutron capture occurs in the graphite, in the coolant, and in the metal cans enclosing the fuel elements.

The importance of developing a reactor graphite of low capture cross section had been long recognised and development had been continuous over the preceding few years. Using a particularly pure coke and observing strict control over plant cleanliness during manufacture, it was possible to produce a reactor graphite with about 80 per cent of the capture cross section of the graphite used in the original Harwell reactor BEPO. The use of this graphite resulted in greatly improved criticality conditions.

The second large source of neutron capture is the material used to can the uranium. The criterion is σ_N, the macroscopic capture cross section in cm^{-1}. The only four possibilities are: beryllium (0·00104 cm^{-1}); magnesium (0·0026 cm^{-1}); aluminium (0·013 cm^{-1}), and zirconium (0·017 cm^{-1}). Beryllium was hard to obtain and difficult to fabricate into a complicated shape like a can with cooling fins. It could be used for the fuel element supports. Zirconium, in the hafnium-free state essential for use in a reactor, was not available in quantity and was incompatible with the chosen coolant. The choice, therefore, lay between aluminium and magnesium. Magnesium had not so far been used, partly because its low capture cross-section only became known in 1948 and partly because reactors had been air cooled and its rapid

[1] Abstracted from "The 1951–53 Harwell Design Study," by R. V. Moore and B. L. Goodlet. Symposium on Calder Works Nuclear Power Plant.

[2] R. V. Moore, "Natural Uranium Reactors—Economic Factors in Power Production." A.E.R.E. Report, 1950, August, No. ERG 11.

[3] Sir C. Hinton, "Nuclear Reactors and Power Production," *Proc. I.Mech.E.*, 1954, 168, page 55; *Chart. Mech. Engr.*, 1954, 1, page 235.

oxidation was feared. In the case of PIPPA,[4] however, the use of a magnesium alloy offered considerable advantages and, after very careful metallurgical investigations, was finally adopted.

Once it had been decided that a graphite-moderated gas-cooled reactor was the best proposition for immediate development, a thorough survey was made of all probable and improbable cooling gases. The following were considered : the inert gases helium, neon and argon ; nitrogen and hydrogen ; methane and other hydrocarbons ; the refrigerants ammonia, sulphur dioxide and freon ; air and steam ; and carbon monoxide and carbon dioxide. The points considered were chemical compatibility with graphite and metals ; decomposition under pile radiation ; induced radioactivity ; neutron absorption ; and heat removal. Whilst this survey showed that helium was best technically, its supply seemed precarious, since it would have to be imported from the United States under the restrictions imposed by the MacMahon Act. Hydrogen was considered and rejected, not only because of its hazardous properties, but its diffusion through the fuel element cans and also into the steel of the pressure vessel was feared. The choice of the only worthwhile alternative, carbon dioxide, was therefore unavoidable. Although as a coolant CO_2 is somewhat inferior to helium, it has the virtues of being abundant, cheap, commercially pure and easy to handle. The fact that it is not chemically inert necessitated intensive experimental work to prove the practicability of using it.

The excess reactivity of the reactor is taken up by a number of 2in boron-steel control rods suspended from flexible stainless steel wires from the drive mechanism. The latter is housed in the vertical branch pipes from the pressure vessel, these branch pipes being cooled sufficiently to provide a satisfactory ambient temperature. When the reactor is being charged or discharged the drive mechanisms are disconnected from the control rods and removed ; the rods themselves remain within the reactor. The flexible suspension allows for limited relative movement between pressure vessel and graphite, while the vertical-stroke system enables gravity to be used as an operating force in the event of an emergency.

Basic Design of Reactor[5]

From the design study four important factors influencing basic design emerged :

(i) Magnesium had been discovered to capture neutrons to a smaller extent than had at one time been thought. This meant that the fuel elements could be contained in a sheath which, though substantial, would none-the-less absorb relatively fewer neutrons than the thin aluminium cans of previous fuel elements.

(ii) The quality of the reactor-type graphite had been improved so much that its absorbing power had dropped nearly 20 per cent below that of the Windscale reactors.

(iii) In air-cooled reactors valuable reactivity is lost by the absorption of neutrons in nitrogen. The decision to use carbon dioxide as coolant made this reactivity available for other purposes.

(iv) The diffusion plant had come into operation. This meant that if necessary a small amount of enriched uranium could be used to improve the reactor charge should the reactivity of the reactor as built be too low for operational requirements. The achievement of a natural-uranium reactor was, however, regarded as of the utmost importance. If this flexibility had not been available the core diameter of the reactor might have had to be about 4ft or 5ft larger to ensure enough reactivity in hand to guarantee the operation of the reactor under design conditions.

These four factors made it possible to specify a core, with 1in diameter rods on an 8in lattice, of active size 21ft long by 31ft diameter. This was much smaller than had been previously thought possible at the desired rating and temperature.

The maximum thickness of plate for the pressure vessel shell which it was considered could be successfully welded on site was 2in. The core diameter and side-reflector thickness gave a pressure vessel diameter of 37ft. These two considerations led to an operating pressure of 100 lb per square inch gauge. It had been found that for given pumping power circumferential fins on the fuel element gave better heat transfer than the longitudinal ones then in use. The resulting higher coolant temperature at outlet from the reactor meant better steam conditions and higher thermal efficiency.

When the design study was completed it was decided to build two reactors at Calder Hall on the lines indicated by the study and the work was transferred to Risley. The emphasis was shifted from electric power to plutonium production and it was therefore necessary to make a new survey of lattice parameters, the pressure vessel size remaining fixed so that construction could proceed in parallel with the detail design of the core. The rest of this paper recounts the work of the three years from March, 1953, which to a certain extent is still continuing. From time to time during these three years improvements were made both in the basic data used and in the methods of calculation. Furthermore, changes were made in the proposed scheme for loading the reactor with natural or enriched fuel, if use of the latter in fact proved necessary.

Nuclear Calculations.—From a reactor-physics viewpoint a Calder Hall reactor consists of a cylindrical block of graphite containing a large number of cylindrical uranium rods spaced on a square lattice. Each rod is clad in a magnesium sheath and is concentrically disposed in a coolant channel, the axes of the channels being parallel with the cylindrical axis of the graphite block. The whole of this graphite block is surrounded by a graphite reflector, 2ft to 3ft thick, the end reflectors being pierced by holes which are a continuation of the coolant channels. There are in addition the following minor features of the design which have to be taken into account. This is done in ways which do not alter the basic model of the reactor outlined above.

The channels containing the fuel elements are, for the convenience of loading and unloading, through the pressure vessel, arranged in square groups of sixteen. At the centre of each square is an additional channel through the graphite block into which a control rod can be inserted. Account is taken of the presence of this channel by a reduction in the apparent density of the graphite, the streaming of neutrons along the channel being neglected.

In making the lattice calculations the uranium rod must be assumed to be continuous along the channel, though in practice the channel contains several short uranium rods with the spaces between them filled by supporting structure. To simplify this picture for calculations, the uranium is assumed to be continuous though of reduced density and the neutron-absorbing power of the intermediate supporting structure is added to that of the main body of the magnesium sheath and distributed uniformly over the length of the uranium.

The experimental results obtained from the start-up programme indicate that some of these minor design features may have been rather too conservatively accounted for in the theoretical work, and this is now being critically reviewed.

For practical purposes the work on nuclear calculations can be divided into three stages, although there is no real separation of one stage from another. The three stages are described in the following three sections.

Preliminary Surveys.—The original PIPPA design study at Harwell had been aimed primarily at the production of electrical power, but when the decision to build the Calder reactors was taken the emphasis was shifted to plutonium production and the design had to be revised to achieve that aim in an economical manner. To examine the possibilities a new survey of lattice pitch and rod diameter combinations was undertaken. It was realised that if the reactor fuel were restricted to natural uranium it might not be possible to build within the limits of the pressure vessel a core giving the required output, e.g. a deficiency of ½ per cent in reactivity would mean a reduction of heat output of about 40 per cent to establish a new reactivity balance.

For this survey the core diameter was fixed at 30ft and for each lattice pitch and rod diameter combination the fuel enrichment was calculated that would make the reactor work at the highest possible power. In all cases the length of uranium was fixed at 20ft. The maximum amount of heat that could be taken out of a single fuel channel with the new circumferentially finned cans was by no means certain, so that the survey also included a small range of maximum channel ratings of from 160–200kW/channel. The results of this survey for the highest channel heat output are shown in Fig. 1. It was clear that the

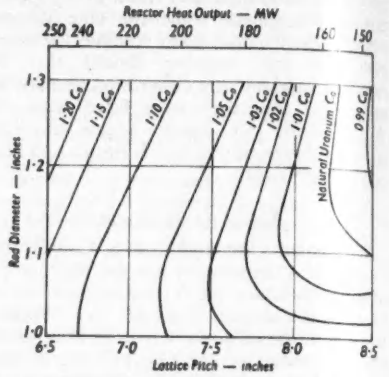


Fig. 1—Lines of constant enrichment on plot of rod diameter against lattice pitch

fuel element had to be of about 1·1in diameter and the lattice pitch not less than 7¼in to avoid a heavy bill for enriched fuel. Further conclusions could not be drawn from these results, however, since the basic information used was known to be rather pessimistic.

A more detailed survey was then made covering a restricted range of lattice pitch and rod diameter combinations, and in addition to a fixed core diameter of 30ft the total heat output of the reactor was also decided. The more important results are shown in Fig. 2. Improved

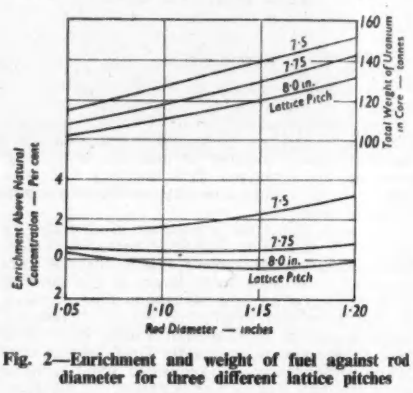


Fig. 2—Enrichment and weight of fuel against rod diameter for three different lattice pitches

data were used so that the enrichment figures in Fig. 2 are far less pessimistic than those in Fig. 1. In the nuclear data uncertainties, of course, remained that might raise or lower the calculated enrichments by about 1 per cent of the naturally occurring value, and the final selection of an 8in lattice pitch, together with a 1·15in diameter fuel element gave the best possible chance of a reactor fuelled with natural uranium operating under design conditions.

Nuclear Calculations for the Calder Reactors as Designed.—When the preliminary surveys were made in 1953 many of the minor details of the reactor core were not yet decided. Such data as the spacing between individual uranium cartridges, the channel diameters, the actual quality of the graphite that would be available and the amount of uranium canning material that would be required were all yet to be determined by the design engineers. The survey calculations were therefore made using rough allowances for all these quantities and assuming that the reactor core would be uniform throughout. By early 1954, however, all the important data affecting the nuclear calculations had been fixed so that a new set of calculations could be made to assess the nuclear parameters of the reactor as it would be built and to determine the enrichment, if any, required for operation. At this time the reactor fuel charge was

[4] The code word for the project : Pressurised Pile Producing Power and Plutonium.

[5] Abstracted from " Basic Design of Reactor," by G. Packman and B. Cutts.

envisaged as being in two parts, a central cylindrical portion of natural uranium fuel elements surrounded by an outer region of slightly enriched uranium, the proportions of each kind of fuel being determined by the enrichment that was convenient for use and the actual reactivity developed by the lattice. The possible error in the lattice constants calculated from the data derived from exponential experiments had been assessed as equivalent to $\pm\frac{1}{2}$ per cent in reactivity, and a convenient method of allowing for this would be by adjustment of the relative proportions of natural and enriched uranium fuels loaded into the reactor at start-up.

The reactor design data used for the nuclear calculations are given in the Appendix to the paper by Moore.[6] The graphite structure is not uniform, but there are variations in channel diameter, and to represent the reactor core a model was chosen with three zones of different channel sizes, the zones being concentric cylinders having axial uniformity.

Fig. 3 shows some of the interesting results. On

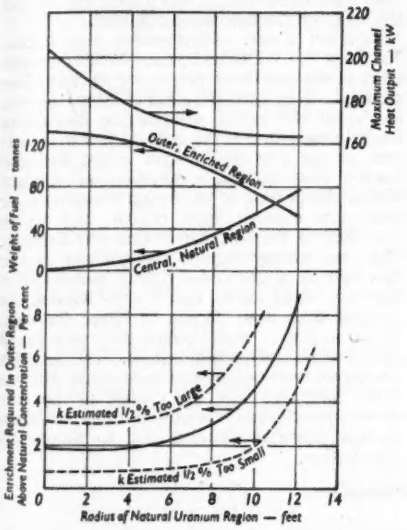

Maximum Channel Heat Output — kW
Weight of Fuel — tonnes
Outer, Enriched Region
Central, Natural Region
Enrichment Required in Outer Region Above Natural Concentration — Per cent
k Estimated ½% Too Large
k Estimated ½% Too Small
Radius of Natural Uranium Region — feet

Fig. 3—Enrichment, maximum channel heat output, and weight of fuel against radius of natural uranium region

this graph can be seen the effect of the uncertainty in reactivity inherent in the calculations. For example, if a 5 per cent enriched uranium fuel were chosen for the outer region the quantity required could be anywhere between 50 and 94 tonnes, a very wide variation indeed.

FINAL REVISION OF CALCULATIONS.—By the middle of 1955 a large number of exponential experiments for graphite-moderated reactors had been completed at Harwell, and from the results a revision of the data used in lattice calculations was made. The effect of the revision was to increase the estimated reactivity of the Calder type lattice by about 0·7 per cent, although the possible uncertainty still remained at $\pm 0{\cdot}5$ per cent. This meant that the fuel charge, instead of including a large proportion of enriched uranium fuel elements, would be almost entirely natural uranium. Furthermore, there was a distinct possibility that the reactor would have some excess reactivity with natural uranium fuel only, so that the reactivity might have to be slightly reduced by adding absorbers and/or removing fuel.

The nuclear calculations were therefore revised once more using the new data, and the new lattice constants for the zones of the reactor core were calculated. Since the reactor could now be expected to operate with a charge of natural uranium, these lattice constants were statistically weighted to give the representative parameters of the equivalent uniform reactor. Recent experience during the start-up experiments has indicated that the use of the so-called "statistical weights theorem" in this way is not satisfactory and that a proper analysis of the three-region core using two-group neutron theory should be used. To "trim" the reactor and allow for the uncertainties in reactivity some steel absorber bars and some enriched uranium fuel elements were provided along with the initial charge of natural uranium fuel. The enriched uranium was rather more highly enriched than before, since it was no longer convenient to produce the lower enrichments in small quantities, but care would have been needed in selecting the channels into which the enriched fuel would be inserted, for its high heat output could cause difficulties.

Coolant Flow Calculations.—In these calculations the unit is the individual fuel element channel. The critical parameters are the coolant inlet and outlet temperatures, the limiting fuel element temperature, the heat removed, and the power to pump the coolant through the channel. The pressure drop depends on the temperatures, so they must be found first. From a set of such calculations it is possible to choose a range of channel heat outputs for which nuclear calculations can be made. These in turn give heat output distributions across the core, and hence the reactor heat output, total coolant mass flow, and bulk outlet temperature. It is implied above that only one cycle of calculations is needed. In fact several cycles are completed before a firm design is reached.

TEMPERATURE DISTRIBUTION ALONG A SINGLE CHANNEL.—Fig. 4 shows the variation of bulk coolant, can surface and central uranium temperatures along the channel. Note that during manufacture of the fuel element the can is pressurised on to the uranium rod. The high external pressure will maintain the two surfaces in good contact while in the reactor. It is therefore expected that the interface temperature drop will not be large, and for simplicity in Fig. 4 the difference between the central uranium and

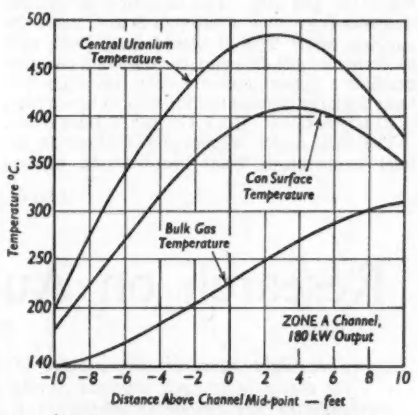


Fig. 4—Variation of central-uranium, can-surface, and bulk-gas temperatures along channel

can surface temperature has been taken as the drop in the uranium only.

PRESSURE DROP.—The channel is split into three parts for calculation.

(1) ENTRY (FROM BOTTOM HEADER TO THE BEGINNING OF THE FUEL ELEMENTS).—This is shown in the paper by Moore. It includes a strut which supports the fuel elements and which carries a disc, known as a "gag," to control the flow of coolant up the channel. When dealing with the whole core the selection of gag size becomes important, but when considering a single channel the minimum overall pressure drop is required, so the entry drop is found for the case where no gag is fitted. Experimental results of entry pressure drop from a rig simulating the channel inlet geometry were expressed as the ratio of pressure drop from the bottom header to the beginning of the fuel elements, to the velocity pressure in the annulus between the gag and the surrounding cylinder. For each channel size they were plotted against gag diameter.

(2) FUEL ELEMENTS.—Guggenheim's equation[7] was used to calculate the pressure drop over the length of channel occupied by fuel elements. Experimental curves of friction factor against Reynolds number were available. It was found that the pressure drop caused by the fuel element top-and-tail assembly was equal to that of the length of finned surface displaced. It was therefore necessary only to substitute the overall length of fuel elements for the total finned length.

(3) EXIT (FROM END OF THE FUEL ELEMENTS TO THE TOP HEADER).—This comprises a parallel portion, and a divergent portion partly in the top graphite reflector and partly in the charge pan. It was treated conventionally.

SINGLE-CHANNEL CHARACTERISTICS.—For given inlet conditions, maximum can surface temperature, and fuel element design, the heat transfer and pressure drop calculations were repeated for a range of mass flows and for the

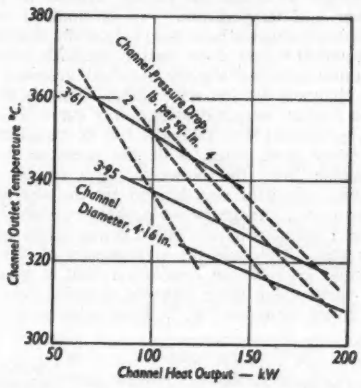


Fig. 5—Channel outlet temperature against channel heat output with lines of constant channel diameter and constant pressure drop

channel sizes used in the experimental rig. Interpolation and extrapolation gave the results shown in Fig. 5.

With the channel diameter, fuel element design and temperature and pressure conditions known approximately, a range of maximum channel heat outputs was chosen for which nuclear calculations were made.

The reactor coolant inlet temperature selected during the design study was 180 deg. Cent. This was reduced to 140 deg. Cent. for Calder to secure increased heat output under the same limitations of blower power, pressure vessel size, and maximum can surface temperature. Further reduction was undesirable because of the resulting

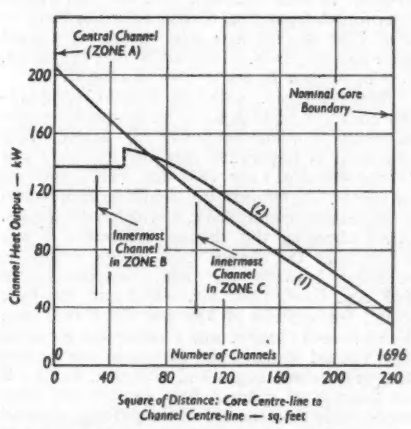


Fig. 6—Channel heat output against position for flattened and unflattened cases

fall in steam pressures, and because the radiation damage to graphite was believed to increase rapidly at temperatures below that chosen.

During the design study, various channel lengths were investigated. A change in length had only little effect on the diameter of core needed for criticality under working conditions and on the channel heat output. The figure of 20ft of uranium was chosen, and was retained for Calder.

REACTOR CORE. CHANNEL DIAMETERS.—From nuclear calculations for conditions suggested by single-channel results, and from practical considerations, the core size and lattice pitch (8in) were chosen, defining the number of channels (1696) and their positions. The next

[6] "The Design and Construction of the Plant," by R. V. Moore. Symposium on Calder Works Nuclear Power Plant.

[7] E. A. Guggenheim, "Compressible Flow of Perfect Gas with Heat Input Distributed Symmetrically About Middle of Channel," Canadian Atomic Energy Report No. 702, National Research Council, Canada, 1945, May; or see J. Diamond and W. B. Hall, *op. cit.*, eqn. (59).

step was the selection of channel sizes. From Fig. 5 it can be seen that for a given pressure drop an increase in outlet temperature can be obtained by decreasing the channel diameter with the heat output. This also means a lower mass flow than if the channel diameter had been kept constant.

The channel heat output distribution curves (Fig. 6) were prepared on the basis of a fixed reactor heat output. The most peaked distribution which it was thought would occur was that given by a single group neutron theory for a uniform core (curve (1)). However, it was felt that some enrichment of the uranium might be necessary to make the reactor critical at full power and temperature. An economical way of doing this would have been to load the channels in a central region of the reactor core with natural uranium and put slightly enriched uranium in the channels outside this region. This method gave the heat output distribution of curve (2).

The channel sizes therefore had to be selected to cover both cases, with the pressure drop available from the blowers. Any change of channel diameter was limited by the charging system to a change between charge groups, all sixteen channels in one group being of the same diameter. This, and the arrangement of charge groups, lead to the conclusion that it would be worth using three different channel sizes in the zones shown on Fig. 7. It was also necessary

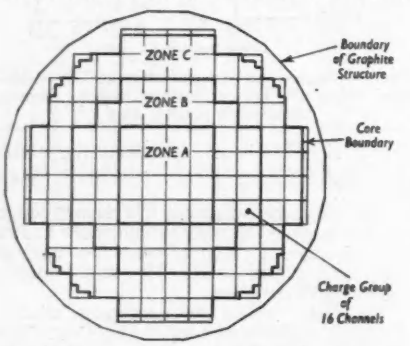


Fig. 7—Arrangement of core zones, charge groups, and side reflector

for ease of charging to keep the channel diameter constant along a channel. For the innermost channel in each zone the greatest heat output was found from Fig. 6, and referring back to Fig. 5 the channel sizes were chosen for a given core pressure drop. They are 4·16in in zone *A*, 3·95in in zone *B*, and 3·61in in zone *C*.

REACTOR CORE. CHANNEL FLOW CONTROL.—To ensure a high bulk outlet temperature and economy in pumping power for a given heat output it is imperative that the relatively low (about 400 deg. Cent. (752 deg. Fah.)) limit set on can surface temperature should be approached in all, and not merely some, fuel element channels. After choosing the channel diameters it was found that the design heat output could be removed between the inlet temperature of 140 deg. Cent. (284 deg. Fah.) and the bulk outlet temperature of 336 deg. Cent. (637 deg. Fah.) if each channel was allowed just the mass flow needed to make the maximum can surface temperature 408 deg. Cent. (766 deg. Fah.). If no attempt at channel flow control had been made other than the use of the different channel diameters, the output and bulk outlet temperature would have been lower by about 25 per cent and 60 deg. Cent. (108 deg. Fah.) respectively, with constant blower power. The combined effect on electrical power output would have been serious.

Even if the distribution of channel heat output across the core were invariable and known accurately, it would be difficult to control the coolant flow up every channel to that channel's exact requirements. It was decided to group channels for flow control purposes, all channels within a group having the same gag size and therefore taking approximately the same flow. Various schemes were considered with different numbers of groups and different arrangements of groups across the core. It was found best to have fewer channels in a group near the centre of the core than near the perimeter. With different numbers of groups it was found that the products (loss in heat output × number of groups) and (drop in bulk outlet temperature × number of groups) were constant at about 96MW and 174 deg. Cent. (313 deg. Fah.) respectively, with constant blower power. It was considered practical to use five groups in zone *A*, nine in zone *B* and nine in zone *C*.

The channel sizes had been chosen on the basis of the reactivity estimates and heat output distributions available at that time, but later when the gag sizes had to be decided there was more confidence that full power and temperature would be reached with the core entirely loaded with natural uranium. At the same time, more refined calculations of heat output distribution, taking into account the different channel diameters and variation of xenon poisoning across the core, became available. For the innermost channel in each zone the heat output (which was the maximum for the zone) was found, and thus the pressure drop across the ungagged channel. This pressure drop was the same for the innermost channel in zone *A* (i.e. central) as for that in zone *B*, but that in zone *C* was smaller. The velocities in the headers are small, so that the header-to-header pressure drop for all channels became equal to that for innermost channels in zones *A* and *B* in the ungagged state. All channels in the innermost flow groups in zones *A* and *B* were therefore left ungagged, and the gagging in the remaining twenty-one flow groups was chosen as described below.

The maximum heat output of a channel in a particular group was found. This gave the mass flow and the pressure drop from the beginning of the fuel elements to the top header. Subtracting this from the header-to-header drop gave the drop to be caused by that flow in the gag, and hence the gag size. The reduction in channel diameter from zone *A* through *B* to *C* made the gagging easier than it would have been with uniform channel diameter, for the small channels produce a greater pressure drop for given flow than the large, leaving less for the gag to produce.

REACTOR CORE. BULK OUTLET TEMPERATURE.—The bulk outlet temperature depends on the inlet temperature, total heat output, coolant specific heat and total coolant flow. The total heat output of the reactor is taken as the sum of that produced in the uranium fuel elements and the surrounding graphite. Heat is also produced in the pressure vessel and in the control rods, but in calculations these are regarded as cooling problems rather than as useful sources of heat.

For the fuel element channels the mass flow through a channel in a particular group was multiplied by the number of channels in the group and the product was summed for all flow groups. This introduces a small error in that non-limiting channels in a group would have lower gas temperatures than limiting ones and, therefore, a slightly greater flow, but this was neglected. Holes were drilled through the plates forming the gas seal between the pressure vessel and the graphite to provide a flow of coolant up the annular space between the side reflector and the wall of the pressure vessel. Annular gaps were left between the restrictors and the impact stools at the bottom of the control rod holes to allow some coolant up these holes.[8] The flows from these three sources were added together and the bulk outlet temperature obtained.

REACTOR CORE. FLATTENING THE RADIAL NEUTRON FLUX DISTRIBUTION.—When the possibility of the core developing more reactivity than required was realised, the effect of using the excess to flatten the radial neutron-flux distribution was investigated. For the same maximum channel heat output this would have meant increased reactor heat output. However, at constant blower power (one of the design limitations) the maximum channel heat output had to be decreased as the flux distribution was flattened. This was mainly because the channel coolant flow had to be controlled tightly irrespective of the flux distribution, and partly because the channel sizes were chosen to cover the cases shown in Fig. 6, where both curves were drawn for the same reactor heat output. The net effect on reactor heat output was an increase that was small compared with the change in the ratio of the mean channel heat output to the maximum. It was therefore decided not to flatten the distribution.

(To be continued)

Research on Automobile Stability

No. I

The Flight Research Department of the Cornell Aeronautical Laboratory has for many years been engaged on the performance of full-scale research on the stability and control of aircraft. A development contract was undertaken for General Motors Research Staff to secure a better understanding of the directional stability and control of automobiles. The lack of flat-road tyre data of a form and completeness suitable for stability and control analyses led to the development of a six-component tyre testing apparatus under a contract with the U.S.A.F.

A SERIES of papers under the general heading of "Research in Automobile Stability and Control and in Tyre Performance" was presented at the Institution of Mechanical Engineers in London at a general meeting of the Automobile Division on Tuesday, November 13 :—

"General Introduction to a Programme of Dynamic Research," by William F. Milliken, jun., and David W. Whitcomb.

"Theoretical Prediction and Experimental Substantiation of the Response of the Automobile to Steering Control," by Leonard Segel.

"A Device for Measuring Mechanical Characteristics of Tyres on the Road," by William Close and Clifford L. Muzzey.

"Tyre Tests and Interpretation of Experimental Data," by Albert G. Fonda.

"Design Implications of a General Theory of Automobile Stability and Control," by David W. Whitcomb, and William F. Milliken, jun.

These papers form an important addition to the literature on the subject of the dynamics of vehicles running on the pneumatic tyre with particular application to the private car, and open up new possibilities in the further analysis, understanding and definition of vehicle handling qualities. The subject is tackled using the already established concepts and terminologies of aeronautical control theory and on the basis of mechanical test results derived from a device for measuring the characteristics of tyres on a flat road. These tyre characteristics are simplified to linear relationships and expressed as constant-valued derivatives, thus allowing a fully mathematical treatment of the subject, which is afterwards substantiated, within certain limits of manœuvring, in the results quoted for practical determinations of the response characteristics of a car under "fixed control" conditions.

The central core of these papers really resides in Part II, where the mathematical analysis of the equations of motion is treated and the results are interpreted and expressed in a form of practical use to the automobile engineer. In view of the importance of this treatment, a complete summary of Segel's paper is present here.

Segel's work involves the application of aircraft analytical techniques to the motor car. Certain methods developed in the Flight Research Department of C.A.L. also proved invaluable in the practical measurement of car response.

The two main problems encountered are :—

I. The development of a mathematical model to replace the physical automobile ; and

II. The utilisation of full-scale response measurements to check the dynamic behaviour predicted by the derived equations of motion.

[8] "Equipment for the Control of the Reactor," by S. A. Ghalib and J. H. Bowen. Symposium on Calder Works Nuclear Power Plant.

Segel then goes on to use the derived theory to discuss certain basic steady state and dynamic properties of the response of the vehicle to steering control.

A Linear Mathematical Model of the Automobile

Philosophy of Approach and Assumptions.—As described by Milliken, it is desirable to treat the car as a linear dynamic system. The advantages are many, particularly in that established experimental techniques may be used. The linearity assumption is later shown to be adequate by the "fit" of practical results. It also allows the use of the principle of superposition and a breakdown of the complex whole problem into simple elements.

Three inputs were first recognised, steering, road and aerodynamic. In the initial work the latter two were disregarded and steering inputs only were studied.

Notation.

A, B, C, E, F—Coefficients of stability quartic.
AT—Aligning torque produced by two front or rear tyres, foot-pounds.
a—Distance between vehicle centre of gravity and front wheel centre, feet.
b—Distance between vehicle centre of gravity and rear wheel centre, feet.
C—C_1+C_2, total cornering stiffness of vehicle, pounds per radians.
C_1—$\partial Y/\partial\alpha_1$, cornering stiffness of both front tyres, pounds per radians.
C_2—$\partial Y/\partial\alpha_2$, cornering stiffness of both rear tyres, pounds per radians.
c—Distance between centre of gravity of rolling mass and the z axis, feet.
D—$\tau\frac{d}{dt}$, non-dimensional derivative operator.
e—Distance between centre of gravity of unsprung (non-rolling) mass and the z axis, feet.
f—Frequency, cycles per second.
g—Acceleration of gravity, feet per second per second.
h—Height of the centre of gravity of rolling mass above the roll axis, feet.
$I_{xz})_s$—Moment of inertia of the rolling mass about a horizontal axis through the centre of gravity of the rolling mass, slug per square foot.
I_x—Moment of inertia of the rolling mass about the x axis, slug per square foot.
$I_{x'}$—Moment of inertia of the rolling mass about the x' axis, slug per square foot.
I_z—Moment of inertia of the vehicle about the z axis, slug per square foot.
I_{xz}—Product of inertia of the vehicle about the x and z axes, slug per square foot.
$I_{x'z'}$—Product of inertia of the vehicle about the x' and z' axes, slug per square foot.
j—$\sqrt{-1}$.
k—Roll stiffness of suspension, foot-pounds per radians.
k_z—Radius of gyration of vehicle mass about the z axis, feet.
L—Rolling moment about x axis, foot-pounds.
l—Wheelbase, feet.
M—Total mass of vehicle, slugs.
M_s—Rolling mass of vehicle, slugs.
M_u—Non-rolling (unsprung) mass of vehicle, slugs.
N—Yawing moment about z axis, foot-pounds.
n_y—Total lateral acceleration along the y axis, g units.
p—Rolling velocity around x axis, radians per second.
R—Radius of steady-state turn, feet.
r—Yawing velocity around z axis, radians per second.
$\hat{r}$—$r\tau$, non-dimensional yawing velocity, radians.
S.M.—Static margin (non-dimensional).
s—Laplacian operator or argument.
t—Tread of vehicle, feet.
V—Forward velocity of vehicle, feet per second.
v—Lateral velocity of vehicle along y axis, feet per second.
W_s—Weight of rolling mass, pounds.
X—Rolling resistance of tyre, pounds.
x, y, z—Body axes fixed in vehicle with origin on the roll axis.
x', y', z'—Body axes fixed in vehicle with origin at the centre of gravity (c.g.).
x_u, y_u, z_u—Body axes fixed in vehicle with origin at the centre of gravity of the non-rolling mass.
Y—Force along y axis, pounds.
$\bar{y}$—Lateral displacement of the centre of gravity of the rolling mass, feet.
Z—Vertical load on tyre, pounds.
z—Height of roll axis above ground.
α—Tyre slip angle, radians.
β—Sideslip angle of vehicle, radians.
γ—Camber angle of front wheels, radians.
ΔZ—Vertical load transfer, pounds.
δ—Steer angle of front wheels, radians.
$\partial AT/\partial\alpha$—Slope of aligning torque versus wheel slip angle, foot-pounds per radians.
$\partial L/\partial p$—Roll damping produced by the shock absorbers, foot-pounds per radian per second.
$\partial X/\partial Z$—Change in rolling resistance with change in tyre vertical loading, pounds per pounds.
$\partial Y_1/\partial\gamma$—Camber thrust per unit camber angle of front wheels, pounds per radian.
$\partial\gamma/\partial\phi$—Rate of change of front wheel camber with respect to body roll, radians per radian.
ε_2—$\partial\delta_2/\partial\phi$, rear roll steer, radians per radian.
λ_1, λ_2—Roots of the characteristic equation (non-dimensional).
μ—$V/\sqrt{(lg)}$, vehicle Froude number.
τ—$\sqrt{(l/g)}$, seconds.
ϕ—Roll angle of the vehicle, radians.
φ—Phase angle, degrees.
φ_{a_b}—Phase angle of a with respect to b, degrees.
ω—Circular frequency, radians per second.
$|\ |$—Absolute value or amplitude.

Subscripts:
ss—Steady state.
1—Front wheel position.
2—Rear wheel position.

Note.—A dot over a symbol means time rate of change.

The human being drives by a combination of steering wheel displacement and torque or "feel." Both these effects can be studied separately. A fixed steering wheel or control by displacement constitutes a "fixed control" characteristic, whereas a free steering wheel or response produced by torque are known as "free control" behaviour.

Additional simplification is possible if the steering system is neglected and response to front wheel angle input is considered. In this respect the essential dynamics are contained in the car "mass" on which also acts the road and aerodynamic disturbances. Therefore, the first efforts were directed at the overall dynamic system of this "mass."

Further assumptions for simplification of the initial work are made. First, it is assumed that it is a fixed control automobile in which the front wheel steering angles are the only force input; secondly, pitch and bounce degrees of freedom are omitted from the mathematical model, this decision being substantiated by practical test; thirdly, forward velocity is included in the model as a major stability parameter, but is not a variable of motion; fourthly, the driving thrust is assumed constant, equally divided between the two rear wheels and ineffective in altering the lateral properties of the tyres in the range treated in this study. Finally, the car is assumed to be a two mass system, constituting a rolling mass constrained to move about a fixed, or roll, axis in the non-rolling mass.

The d'Alembert or Inertia Forces.—In order to obviate unwieldy problems associated with momenta in space axes, the stability axes are fixed relative to the car, as shown in Fig. 1.

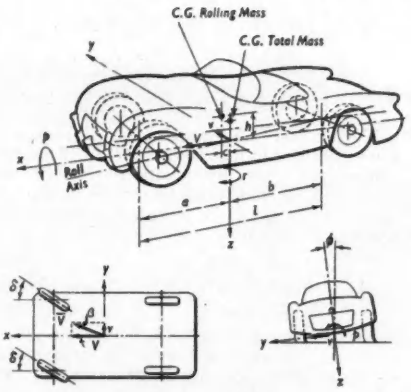


Fig. 1—Axis system for simplified automobile

The x axis is parallel to the ground through the point where the car's actual roll axis intersects the z axis, which, in turn, is perpendicular to the ground through the centre of gravity of the whole car. The y axis is lateral through the common intersection of the x and z axes, and perpendicular to the plane of symmetry of the rolling car body. The whole system rolls with the car, which effect Segel neglects for small roll angles. He justifies this step by reference to a later treatment assuming axes located relative to the non-rolling mass, which yielded identical results. From this, the lateral velocity v and the yaw velocity r are assumed to be the same as in ground axes. For small vehicle sideslip angles β the velocity V along the x axis is assumed equal to the resultant velocity. Making the assumption that the centre of gravity of the non-rolling mass lies on the x axis, the rate of change of linear and angular momenta may be expressed with reference to a new parallel axis system (x', y', z') with its origin at the centre of gravity of the entire car.

$$\Sigma Y' = M(\dot{v}' + Vr) \quad . \quad . \quad . \quad (1)^*$$

$$\Sigma N' = I_{z'}\dot{r} + I_{x'z'}\dot{p} \quad . \quad . \quad . \quad (2)$$

$$\Sigma L' = I_{z'}\dot{p} + I_{x'z'}\dot{r} \quad . \quad . \quad . \quad (3)$$

where

$$I_{x'z'} = \frac{M_s M_u}{M} h(c+e) = M_s hc$$

* The numbers are those used by L. Segel: "Theoretical Prediction and Experimental Substantiation of the Response of the Automobile to Steering Control."

Equations (1) through (3) may be transformed to the x, y, z axes by noting that

$$\dot{v}' = \dot{v} + \frac{M_s}{M}h\dot{p} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

and

$$\Sigma L = \Sigma L' + \frac{M_s}{M}h\Sigma Y' \quad . \quad . \quad (5)$$

The d'Alembert forces and moments with respect to the desired axis system are finally obtained as

$$\Sigma Y = M(\dot{v} + Vr) + M_s h\dot{p} \quad . \quad . \quad . \quad . \quad (6)$$

$$\Sigma N = I_z\dot{r} + I_{xz}\dot{p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\Sigma L = I_x\dot{p} + M_s h(\dot{v} + Vr) + I_{xz}\dot{r} \quad . \quad . \quad (8)$$

where

$$I_z = I_{z'}$$

$$I_{xz} = I_{x'z'}$$

$$I_x = I_{x'} + M\left(\frac{M_s}{M}h\right)^2 = I_{cg})_s + M_s h^2$$

In equation (6), it is seen that the side-force inertia reaction terms, from left to right, are respectively the result of (1) linear, and (2) centrifugal acceleration of the total mass, and (3) linear acceleration of the centre of gravity of the rolling mass caused by rolling acceleration about the roll axis. Equation (7) indicates that the external yawing moment is equal to the product of yawing moment of inertia and yawing acceleration plus the product of rolling acceleration and the product of inertia I_{xz}. The d'Alembert moment about the roll axis, as given in equation (8), is equal to the product of the rolling moment of inertia and rolling acceleration plus the moment of the linear and centrifugal acceleration of the rolling mass about the roll axis plus the product of yawing acceleration and the product of inertia.

The External Forces and Moments Acting on an Automobile

The desired mathematical model is obtained on equating the inertia reactions (side force, yawing moment, and rolling moment) to their respective external force and moment summations. The external side force and yawing moment acting on the automobile are created in the ground plane and are derived from the force reactions between the tyre and the road. The roll moment about the roll axis, on the other hand, is produced by the spring suspension, the shock absorbers, and gravitational forces.

As indicated earlier, the external forces and moments are assumed to be linear functions of the independent variables of motion. This assumption appears to be valid, since tyre data acquired to date indicate that the side force and moment properties of a pneumatic tyre do vary linearly with the slip and camber angles, if these angles are restricted to reasonably small amplitudes.

Using the usual automotive and tyre nomenclature for slip angle, cornering force, aligning torque, camber angle and camber thrust, the slope of the cornering force curve versus slip angle is $\partial Y/\partial\alpha$, and is known as the cornering stiffness C. The slope of the aligning torque and camber

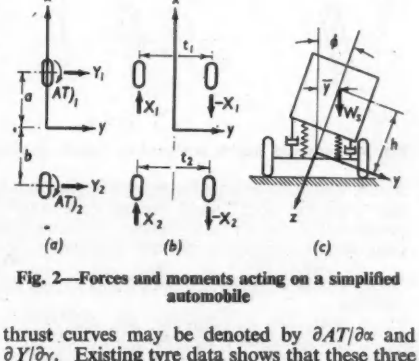


Fig. 2—Forces and moments acting on a simplified automobile

thrust curves may be denoted by $\partial AT/\partial\alpha$ and $\partial Y/\partial\gamma$. Existing tyre data shows that these three terms vary with load transfer effects, but this is neglected in order to retain linearity. Experience has shown that this effect is second order, since the combined properties of both front and rear tyres are approximately constant for lateral

accelerations up to 0·3 g. The car may now be collapsed into the x–z plane and possess one front and one rear wheel exhibiting the total properties of both front and both rear wheels, providing that the yawing moments produced by unsymmetrical changes of rolling resistance arising from load transfer are not omitted. This variation is denoted by the derivative $\partial X/\partial Z$.

The forces and moments acting on this simplified automobile are shown in Fig. 2. The subscript 1 denotes forces and moments arising from the front tyres and the subscript 2 is used for the rear tyres.

From Fig. 2 :

$$\Sigma Y = Y_1 + Y_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

From Fig. 2 *a* and *b* :

$$\Sigma N = aY_1 + AT)_1 + t_1X_1 - bY_2 + AT)_2 + t_2X_2 \quad . \quad (10)$$

From Fig. 2 *c* :

$$\Sigma L = W_s\bar{y} + L)_{springs} + L)_{shock\ absorbers} \quad . \quad . \quad . \quad (11)$$

Note that the right-hand sides of equations (9), (10) and (11) can be expressed in terms of the assumed linear tyre and suspension characteristics of the automobile. From the previous discussion, it is seen that :

$$Y_1 = C_1\alpha_1 + \frac{\partial Y_1}{\partial \gamma}\frac{\partial \gamma}{\partial \phi}\phi \quad . \quad . \quad . \quad (12)$$

$$Y_2 = C_2\alpha_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$AT)_1 = \frac{\partial AT}{\partial \alpha_1}\alpha_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

$$AT)_2 = \frac{\partial AT}{\partial \alpha_2}\alpha_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

$$X_1 = \frac{\partial X}{\partial Z}\Delta Z_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

$$X_2 = \frac{\partial X}{\partial Z}\Delta Z_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$\bar{y} = h\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

$$L)_{springs} = (k_1 + k_2)\phi = k\phi \quad . \quad . \quad . \quad (19)$$

$$L)_{shock\ absorbers} = \left[\left(\frac{\partial L}{\partial p}\right)_1 + \frac{\partial L}{\partial p}\right)_2\right]p \quad . \quad . \quad (20)$$

Furthermore, the front and rear slip angles, (α_1 and α_2), can be expressed in terms of the independent variables of motion. If small perturbations are assumed, the front and rear slip angles can be expressed as shown in Fig. 3. In this

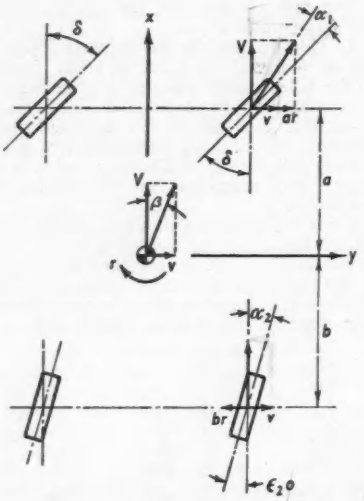


Fig. 3—Tyre slip angles produced by vehicle motion

figure, it should be noted that $\epsilon_2 = \partial\delta_2/p\phi$, and is the " rear roll steer " as determined by geometric properties of the rear suspension. The resulting equations for front and rear tyre slip angles are :

$$\alpha_1 = \beta + \frac{ar}{V} - \delta \quad . \quad . \quad . \quad . \quad . \quad (21)$$

$$\alpha_2 = \beta - \frac{br}{V} - \epsilon_2\phi \quad . \quad . \quad . \quad . \quad (22)$$

The front and rear load transfer terms, ΔZ_1 and ΔZ_2 are also expressible in terms of the independent variables of motion. For example, the load transfer quantity, ΔZ_2 can be determined by considering the forces and moments acting on the rear suspension of the automobile. The indicated moments resulting from positive rolling and displacement of the rolling mass as caused by the rear shock absorber and rear suspension roll stiffness, respectively, are $-\left(\frac{\partial L}{\partial p}\right)_2 p$ and $-k_2\phi$. (The minus signs are necessary since the quantities $\partial L/\partial p$ and k were previously defined with respect to forces acting on the rolling mass.) The force Y'_2 is the inertia reaction acting at the hypothetical pin joint between the rolling and non-rolling masses. If the inertia of the unsprung mass is neglected in comparison to the rolling mass, then this force Y'_2 is equal and opposite to Y_2, the force acting on the tyre by the road. If

$$Y'_2 = -Y_2,$$

the following result is obtained for the rear load transfer by taking moments about point B :

$$\Delta Z_2 = \frac{1}{t_2}\left[Y_2z_2 + k_2\phi + \frac{\partial L}{\partial p}\right)_2 p\right] \quad . \quad . \quad (23)$$

In a like manner, the incremental vertical load on the front tyres is found to be

$$\Delta Z_1 = \frac{1}{t_1}\left[Y_1z_1 + k_1\phi + \frac{\partial L}{\partial p}\right)_1 p\right] \quad . \quad . \quad (24)$$

From equations (12), (13), (21) and (22) it is seen that

$$Y_1 = C_1\left(\beta + \frac{a}{V}r - \delta\right) + \frac{\partial Y_1}{\partial \phi}\phi \quad . \quad . \quad (25)$$

$$Y_2 = C_2\left(\beta - \frac{b}{V}r - \epsilon_2\phi\right) \quad . \quad . \quad . \quad (26)$$

Substituting (25) and (26) in equations (23) and (24), the following equatio .s for front and rear load transfer are obtained :

$$\Delta Z_1 = \frac{1}{t_1}\left[z_1C_1\left(\beta + \frac{a}{V}r - \delta\right) + z_1\frac{\partial Y_1}{\partial \phi}\phi + k_1\phi + \frac{\partial L}{\partial p}\right)_1 p\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

$$\Delta Z_2 = \frac{1}{t_2}\left[z_2C_2\left(\beta - \frac{b}{V}r - \epsilon_2\phi\right) + k_2\phi + \frac{\partial L}{\partial p}\right)_2 p\right] \quad . \quad (28)$$

If equations (12) through (22), (27,) and (28) are substituted in the external force and moment summations given by equations (9), (10) and (11) lengthy and complex relationships are obtained which can be represented functionally as follows :—

$$\Sigma Y = f(\beta, r, \delta, \phi) \quad . \quad . \quad . \quad . \quad (29)$$

$$\Sigma N = f(\beta, r, \delta, \phi, p) \quad . \quad . \quad . \quad (30)$$

$$\Sigma L = f(p, \phi) \quad . \quad . \quad . \quad . \quad . \quad (31)$$

These functional relationships can be greatly systematised and abbreviated by use of derivative notation. Thus, equations (29), (30) and (31), when expanded, can be expressed as :

$$\Sigma Y = \frac{\partial Y}{\partial \beta}\beta + \frac{\partial Y}{\partial r}r + \frac{\partial Y}{\partial \delta}\delta + \frac{\partial Y}{\partial \phi}\phi \quad . \quad . \quad . \quad (32)$$

$$\Sigma N = \frac{\partial N}{\partial \beta}\beta + \frac{\partial N}{\partial r}r + \frac{\partial N}{\partial \delta}\delta + \frac{\partial N}{\partial \phi}\phi + \frac{\partial N}{\partial p}p \quad . \quad . \quad (33)$$

$$\Sigma L = \frac{\partial L}{\partial p}p + \frac{\partial L}{\partial \phi}\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

(To be continued)

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

METHODS OF SAMPLING WATER USED IN INDUSTRY

No. 1328 : 1956. Price 6s. When first published in 1946 this specification was entitled " Methods of Sampling Water Used in Steam Generation." This revised edition covers requirements for the sampling and physical testing of water used in industry, and it deals with size of the sample, with containers and their labelling, and with the sampling of water of the following types :—Raw water ; treated or softened water ; feed water ; boiler water ; condensate and distillate ; water from vessels under reduced pressure, and water for the determination of dissolved oxygen.

More attention has been paid in this new standard to relating the size of the sample and the type of container to the tests that are likely to be required on the sample. Similarly, the suitability of new materials for containers has been taken into account, and the methods of sampling have been revised in detail and brought into line with modern practice. A description has been included of the submerged bottle technique for sampling for dissolved oxygen determination, and an appendix is included covering the determination of this constituent by the starch method.

African Engineering News

BY OUR SOUTH AFRICAN CORRESPONDENT

Titanium Oxide from Beach Sands

The Anglo-American Corporation has recently acquired the assets of the Titanium Corporation at Umgababa on the Natal South Coast and intends to embark on the production of titanium oxide, the paint base so much in demand in modern industry, by the erection of a new factory at Umbogintwini, where the African Explosive and Chemical Industries have joined forces with British Titanium Products, in this venture. On the rising lands known as Ilmenite Hill between Umgababa and the Umzimbazi River, the sands comprising the first 50–100ft of the hill alone have been shown to carry from 5 per cent to over 20 per cent ilmenite in the lower levels. Ilmenite Hill by itself was, in 1951, proved to contain 21,500,000 tons of exploitable sands averaging 9·2 per cent ilmenite or nearly 2,000,000 tons of ilmenite mineral. In addition, nearly 2 per cent, or 400,000 tons, of heavy minerals—zircon, rutile, garnets and traces of monazite—were proved.

Pilot plant tests at the time showed that the sands could readily be treated in spiral separators with sea water to yield an 80 per cent ilmenite concentrate. This primary concentrate, after washing and drying, was readily amenable to magnetic separation, and a product containing 96 to 97 per cent ilmenite and 1 per cent each of rutile, zircon and other heavy minerals, was obtainable. This secondary concentrate assayed over 50 per cent titanium oxide and contained only slight traces of chrome, phosphorus and vanadium. The new plant at Umbogintwini will have an initial annual capacity of 8000 tons of pigments, and will be laid out conveniently for extension, bearing in mind overseas experience that titanium-pigment manufacture is a rapid-growth industry.

In the production process ilmenite arrives at the factory as a wet rather coarse black sand. After drying, it is ground in air-swept ball mills to ensure small and constant particle size. Ilmenite and concentrated sulphuric acid are then agitated together in large lead-lined reinforced concrete vessels. The temperature of the mixture in the vessels is raised until a vigorous reaction occurs, the product of which is a brownish-green friable mass consisting of titanyl sulphate and iron sulphate. This is dissolved in water and the crude solution passed to settling tanks for clarification. The clear liquor is cooled and the copperas which crystallises is then removed by centrifugal action. Copperas itself has a limited number of commercial uses, as, for example, in water treatment. The remaining liquor is concentrated and hydrolysed at boiling point, which causes the hydrated titanium oxide to precipitate from the solution in a flocculent state. The hydrated titanium dioxide is next thoroughly washed in a battery of rotary filters to ensure the removal of all impurities. The resulting titanium dioxide pulp is subjected to heat treatment in long calciners. Before packing, the calcined pigment is subjected to intense milling, thus ensuring that any oversize particles in the final product are broken down.

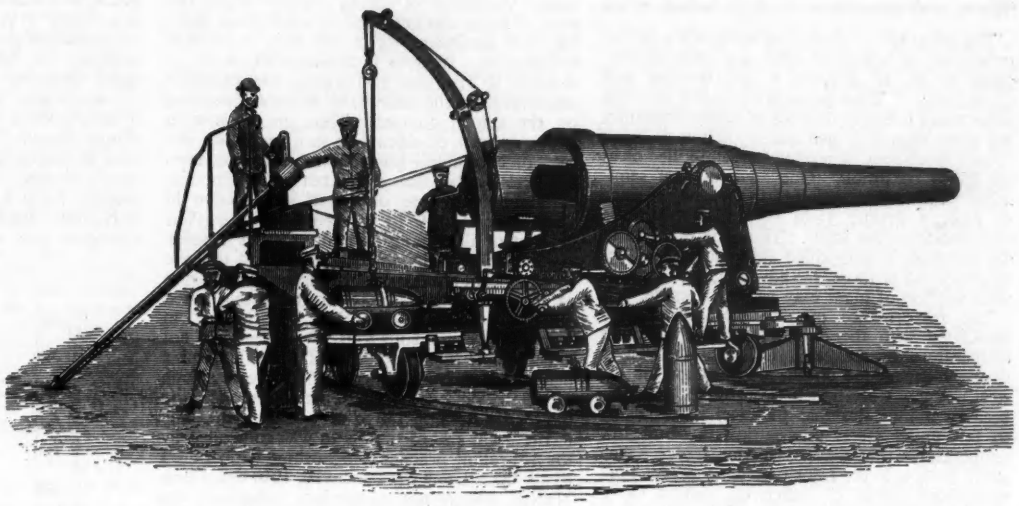
Kyle Dam Project

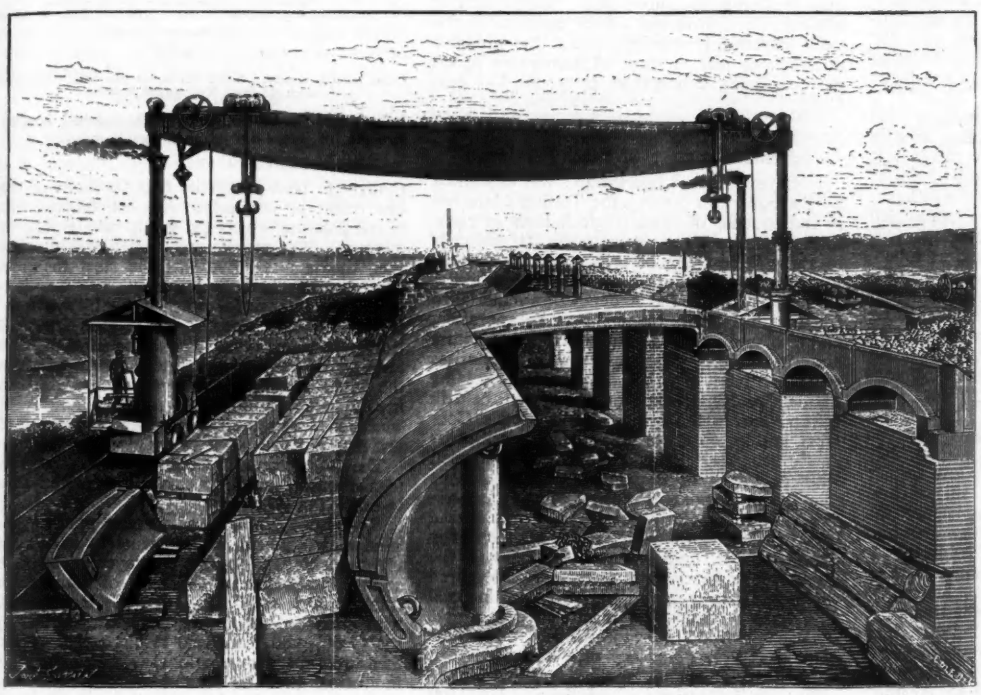
The Southern Rhodesia Minister of Roads and Irrigation has recently referred to the establishment of a hydro-electric scheme as a possible development of the Kyle dam project, near Fort Victoria. Investigations were being made into the hydro-electric potential of the area and it had already been indicated that it would be possible to erect a plant with a generating capacity of some 9400kW. The dam would be 173ft high, and the capacity would be 800 million acre-feet, or four times that of Lake McIlwaine : the Government would try to start the actual construction of the dam in 1957–58.

THE DIESEL ON RAIL—A new film "The Diesel on Rail," made for Shell-Mex and B.P., Ltd., by North Court Films, with the co-operation of the British Transport Commission, is designed to aid the maintenance staff of British Railways. Emphasis throughout the film is on the fact that lubricants and fuel must be kept clean. This film is available in 16mm and 35mm sizes.

ENGRAVINGS OF 1879

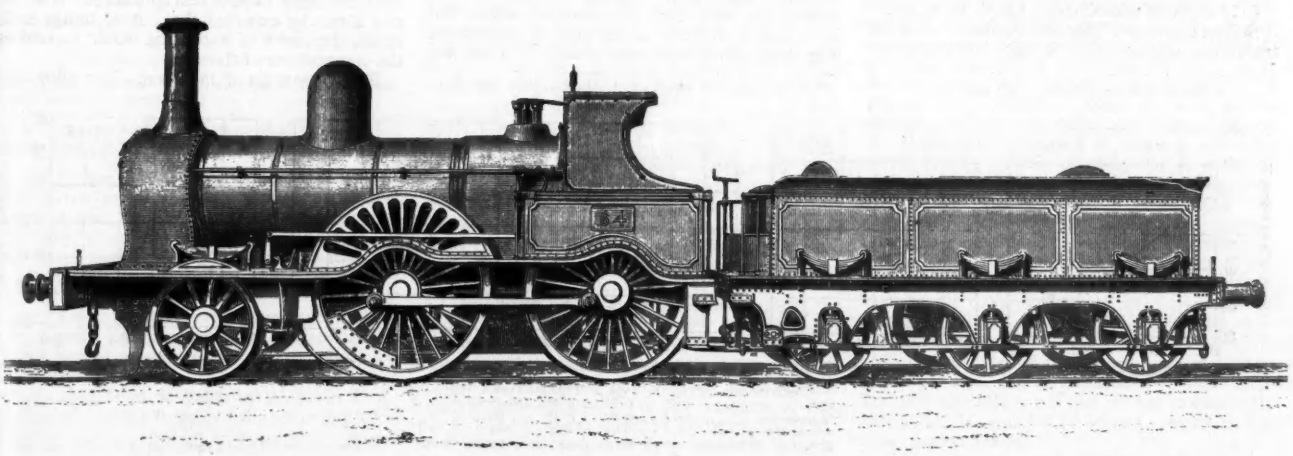
In our issue of August 15, 1879, there was printed an account of some artillery experiments at Meppen, at which "almost every nation was represented." The right-hand engraving illustrates a 14in Krupp gun mounted on a coast-carriage. The weight of the gun was 51 tons, and our comment about it was that "the working of the gun was very good and the rate of firing rapid." Our correspondent who was present at the experiments added: "the arrangements for the reception of the guests were wonderfully complete!"





The St. Marie Battery "in course of construction" is illustrated by the left-hand engraving, reproduced from our issue of December 26, 1879. The engraving was included in an article on Herr von Gruson's chilled cast iron armour, which, our article says, "has been now adopted on so large a scale abroad that it is high time that we became acquainted with it in this country." The St. Marie battery was erected for the defence of Antwerp, the Gruson armour having a maximum thickness at portholes of 27·56in.

Below, there is reproduced from our issue of September 5, 1879, an engraving illustrating an express passenger engine for the Great Southern and Western Railway, Ireland. It was built at the Inchicore works, where the 100th locomotive had been but recently completed. Our reference to the locomotive illustrated runs: "we can speak in very high terms of No. 64, a trip of eighty-four miles on the footplate demonstrating that the engine runs easy, keeps steam admirably, and carries her water unusually well. There was not a trace of priming even with a full glass."



Metallurgical Topics

Silicon and Aluminium in Hot-Rolled Steel

THE influence of silicon and aluminium on the properties of hot-rolled steel has been investigated by R. H. Frazier, F. W. Boulger and C. H. Lorig.* Their paper deals mainly with the impact and tensile properties of steels containing not more than 0·25 per cent of carbon.

Such steels may be used in the semi-killed or in the killed condition. One advantage of semi-killed steels is that, owing to the relative absence of pipe, a greater yield of useful product is obtained from the ingot. Thus, for example in shipbuilding, if semi-killed steel plates are adequate for the purpose, the advantage of a higher yield per ton of ingot may be considerable.

The performance of ship plates is closely associated with the ductile-to-brittle transition temperature of the steel, and this in turn is strongly dependent on the composition of the steel. A low transition temperature is desirable because it indicates that the steel is less likely to fail under stress concentrations or at low temperatures that may be encountered. Killed steels have a lower transition temperature than semi-killed steels of otherwise similar composition. The better qualities of the killed steel in this respect are mainly due to its lower oxygen content. The principal deoxidisers, aluminium, silicon, and manganese, lower the oxygen content, the amount of oxygen remaining after the addition of one of these three elements being influenced by the amounts present of the other two.

In their investigation Frazier, Boulger and Lorig employed eleven kinds of steel differing slightly in carbon, but mainly in manganese content, and to these various amounts of silicon and aluminium were added. Ninety-five different compositions were hot rolled into plates ¾in thick, the finishing temperature being in every case 1010 deg. Cent., and were tested as rolled. Charpy keyhole specimens were taken parallel to the direction of rolling and notched normal to the surface of the plate. Four tests on each steel were made at intervals of 10 deg. Fah. in a pendulum machine with 30 kilogramme-metres striking energy. Four Kahn tear test specimens were also broken at intervals of 10 deg. Fah. throughout the transition zone. The actual transition temperatures recorded vary to some extent according to the criterion by which they were determined, but relatively they give similar indications of the influence of silicon and aluminium. In the accompanying figure the influence of silicon on the transition temperature of five of the eleven kinds of steel is illustrated, the criterion employed being the temperature at which the keyhole Charpy impact value fell to 12ft-lb. Judged by this criterion, the transition temperature was reduced by about 1·5 deg. Fah. for each increase of 0·01 per cent silicon up to the following silicon contents :—

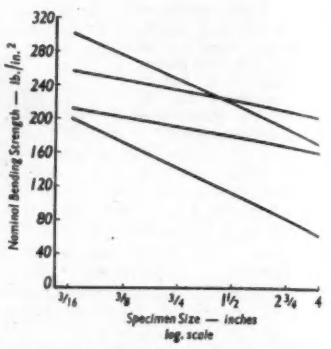
0·50 in steels with C 0·25, Mn 0·45, Al nil.
0·40 in steels with C 0·21, Mn 0·75, Al 0·03.
0·17 in steels with C 0·21, Mn 0·75, Al nil.

Silicon above 0·17 per cent tended to raise the transition temperature of the last-mentioned steel. Variations of silicon content within the narrow range characteristic of semi-killed steels had no significant effect on their transition temperature. Increase in aluminium content up to about 0·2 per cent also lowered the transition temperature of the steels by an amount depending on the silicon content. Thus, in steels with 0·03 per cent of silicon or less, each 0·01 per cent of aluminium lowered the transition temperature by 3·7 deg. Fah., but equal amounts of aluminium were only half as effective in steels containing 0·13 per cent of silicon. The amount of aluminium normally present in steels made by fine-grain practice was found to have no significant effect on the transition temperature of these induction furnace melted steels tested in the hot-rolled condition. Variations in aluminium content up to 0·27 per cent did not affect the tensile properties of these hot-rolled plates, but each increase of 0·01 per cent silicon raised the yield point 130 lb per square inch and the tensile strength 150 lb per square inch. The ferrite grain size of the plates was controlled by the hot-rolling practice, the finishing temperature of all plates being the same, viz., 1010 deg. Cent. Neither silicon nor aluminium influenced the grain size of the hot-rolled steels, but the coarsening temperature was in all cases lower than the finishing temperature. Normalising at 900 deg. Cent. produced a finer grain size in the steels containing aluminium, and the presence of 0·01 per cent or more of aluminium raised the coarsening temperature by about 110 deg. Cent.

* *Journal of Metals*, October, 1956, page 1269.

Brittle Fracture of Steel Forgings

LAST year a new " task group " was appointed by the American Society for Testing Materials in consequence of three tragic failures of rotor forgings in generators or turbines. Its object is to study " the cause of brittle fracture in steel forgings with the aim of establishing a criterion by means of which the tendency of a material to fracture in a brittle manner may be appraised, and also to discover the cause of brittle fracture and its cure." The task group comprises representatives of eight companies, holding frequent meetings, some of which were held in Europe during the recent World Metals Congress, and its work has been briefly described by A. O. Schaefer.* The group is not concerned with questions of design, though they insist that the importance of design cannot be overemphasised. Metallurgical and mechanical irregularities, however, become of increasing importance at high strength levels, and the utmost in resistance to brittle fracture is required when such irregularities exist. The normal tensile and notched-bar impact tests do not give sufficient information to furnish a reliable opinion as to the tendency of a steel forging to brittle fracture. Poor ductility and low impact values are indications of brittleness, but high ductility and good impact values do not necessarily mean that the material cannot fail in a brittle manner under certain conditions. The transition-temperature range in which the results of notched bar impact tests fall off rapidly is probably of greater importance. Lowering of the transition temperature decreases the general tendency to brittle fracture. Data are also being obtained from notched bar bend tests on specimens cut from forgings, machined in several sizes, notched, and bent to fracture as simple beams. In all cases the unit breaking load decreased as the cross section of the specimen increased. If the results of such tests are plotted, using a log scale for the specimen size only, approximately straight lines result. Typical examples are shown herewith. There was



Cross section, square. Notch depth, 20 per cent. Angle of notch, 45 deg. Root radius, 0·003in.

Influence of size of test piece on the notched bending strength of nickel-molybdenum-vanadium rotor steels

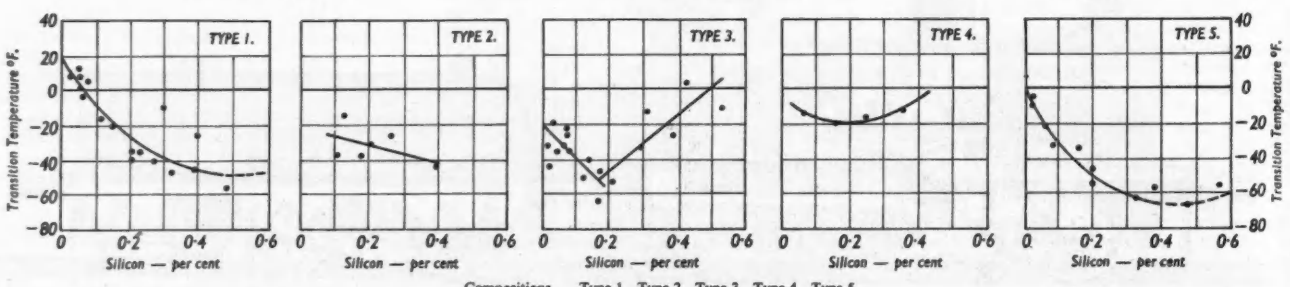
thought to be a possibility that the slope of the line might be connected with the tendency to brittle fracture which the group was trying to measure. The more nearly horizontal the line was, the less sensitive was the steel to stress concentrations and the lower was its transition-temperature range for notched bar impact tests. It was, however, not considered that either the transition-temperature range for notched bar tests or the multiple-size notched bend test gave the whole answer. Moreover, both these tests involve the machining of a large number of specimens and require a considerable amount of test material.

The task group has devoted much attention to methods of making rotors still less susceptible to brittle failure :—

By Heat Treatment.—American practice has been based on air cooling, whereas in Europe oil quenching is usually employed, subject to certain limitations on the basis of diameter or total mass or total alloy content. Experiments with quenched rotors are being carried out by the Group with beneficial results on properties measured in the conventional way, but there are indications that the benefits are to be found in the surface metal only and will not extend to a sufficient depth to be of real advantage. It would, of course, be expected that, other things being equal, the depth of hardening would depend on the composition of the steel.

By Composition of the Steel.—The alloy steel

* *Trans. Amer. Soc. Mech. Engrs.*, October, 1956, page 1623.



Compositions	Type 1	Type 2	Type 3	Type 4	Type 5
Carbon	0·25	0·21	0·21	0·19	0·21
Manganese	0·45	0·60	0·75	1·00	0·75
Aluminium	Nil	Nil	Nil	Nil	0·03

Specimen 10×10mm, notch 5mm deep, root radius 1mm

Influence of silicon on the 12ft-lb keyhole Charpy transition temperature of five kinds of steel (Frazier, Boulger and Lorig)

mainly used in rotor manufacture in the U.S.A. is a nickel-molybdenum steel containing nickel 2·75 per cent, molybdenum 0·5 per cent and vanadium 0·05 to 0·1 per cent. This steel usually contains some chromium but less than 0·20 per cent. A similar steel with higher chromium has been used when higher strength is required. A greater variety of steel is used in Europe, but, apart from the use of carbon steel and carbon-molybdenum steels for more lightly stressed rotors, a higher-chromium steel is preferred for the reason that it has a greater uniformity of properties in large sections. The task group is planning to liquid-quench some forgings of European composition, and some of an alloy steel of still higher hardenability which might be worth while if larger sections can be quenched effectively.

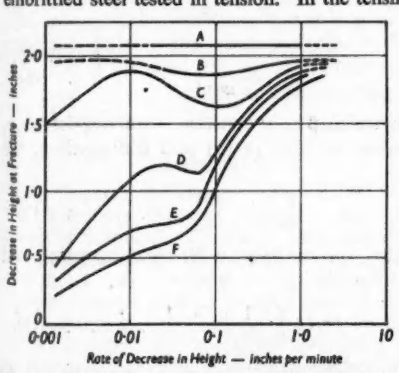
By Vacuum Pouring Technique.—The idea of vacuum pouring was described first by Bochumer Verein as a means of avoiding hairline cracks, and they have succeeded in markedly reducing the incidence of this defect by their pouring technique. The further question arises as to the value of vacuum pouring as a means of improving inherent ductility and toughness. Rotors made from ingots produced in Germany by this technique are being obtained and consideration is being given to the installation of a plant for the vacuum pouring of large ingots in order to ascertain at first hand and as quickly as possible the value of vacuum pouring in counteracting any tendency to brittle fracture.

The task group does not at present offer any suggestions for modifying existing methods of inspection, but records the opinion that ultrasonic methods are likely to become of increasing importance.

Hydrogen in Steel

A BRIEF account of the various effects of hydrogen in steel has recently been published by C. R. Simcoe*, of the Battelle Memorial Institute. These are mostly of a deleterious character: reduced ductility, tendency to the formation of hairline cracks in forgings and fish-eyes in welds, and embrittlement of electroplated components. High-strength steels used for aeroplane landing gear have shown pronounced susceptibility to embrittlement during plating, and the effect of hydrogen becomes apparent in the delayed failure of parts which have been continuously under a relatively low load.

The rate of strain is well known to have an influence on the ductility shown by hydrogen embrittled steel tested in tension. In the tensile

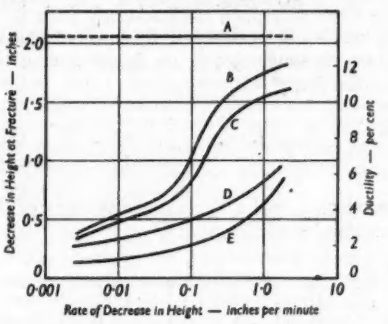


Curve *A*, not embrittled; *B* five minutes, *C* fifteen minutes, *D* twenty minutes, *E* twenty-five minutes, *F* forty minutes.

Fig. 1—Tests on spring steel cathodically treated for various times at a density of 4mA per square inch

test the presence of hydrogen does not appreciably affect the stress-strain relation up to the maximum load, but its effect may then become evident by a marked decrease in reduction of area. Until necking begins to occur the stress in the tensile test is uniaxial tension. In tensile tests on notched specimens triaxial stresses associated with a high stress gradient are present. In such tests the maximum load sustained is reduced by the presence of hydrogen especially in high-strength steels.

It was considered desirable by W. Beck, E. P. Klier and G. Sachs† to study hydrogen embrittlement in a test in which the stress gradient was present while the accompanying triaxiality was only mild. The bending of thin strips satisfies these requirements. These investigators have described a simple bend test in which a thin strip is bent as a column. The test is characterised by a nearly linear increase in strain with reduction in height of the column, and is therefore a constant strain rate test. The paper contains results of tensile and bend tests obtained in the study of the embrittlement of heat-treated



Curve *A*, not embrittled, *B* 4mA per square inch, *C* 12mA per square inch, *D* 80mA per square inch, *E* 200mA per square inch

Fig. 2—Tests on spring steel cathodically treated for forty minutes at various current densities

0·7 per cent carbon spring steel (Rockwell hardness R_c 48) induced by cathodic treatment in 10 per cent sodium hydroxide solution at 30 deg. Cent. The specimens were 3in high, 0·5in wide and 0·06in thick, rounded to a semicircle at top and bottom ends. They were tested immediately after impregnation with hydrogen or stored for not more than three hours at −75 deg, Cent. before testing. The variables included current density and time of charging: rate of strain and recovery temperature and time. (Some tests were also made on alloy steel bolts.)

After mild cathodic treatment embrittlement did not develop within the range of strain rates investigated (Fig. 1, *B*). As the time of cathodic treatment was increased the embrittlement passed through a maximum and then a minimum value as the rate of strain was reduced (Fig. 1, *C*, *D*). With still higher hydrogen content a gradual decrease in ductility occurred from high ductility for high rates of strain to a fairly constant low value for low strain rates (Figs. 1 and 2). Finally, for the most severe cathodic treatments the ductility remained low for all the rates of strain employed (Fig. 2).

The spring steel tested recovered its ductility fairly rapidly at room temperature. Approximately 50 per cent of the specimens showed a ductility halfway between the values for the embrittled and the non-embrittled conditions after resting for one hour at 20 deg. Cent. or for two hours at 2 deg. Cent., or for one day at −75 deg. Cent. On the other hand, it appeared that recovery did not take place during prolonged testing periods at room temperature. The ductility of severely embrittled specimens remained very low when the rate of straining extended the testing time to a period of several hours. With low hydrogen content its effect could be recognised in tests extending over several days. The recovery under load in the bend test was evidently different from the recovery of unstressed specimens. For this paradox, which needs further investigation, two possible explanations are put forward by the authors; either the recovery may be greatly retarded by the application of a load, or the effect of a slow rate of strain may compensate for, and obliterate, the effect of recovery under a wide range of conditions.

In comment on these explanations it might be suggested that, assuming recovery to be due to the interstitial diffusion of atomic hydrogen outwards, the existence of a state of stress might favour the formation of molecular hydrogen at imperfections opened up in the structure of the metal and so cause these to become points of local disruption contributing permanent damage to the ductility of the metal.

Electrolytic Titanium

OVER a long period efforts have been made to prepare titanium by electrolytic methods, and the recent increase in demand for the metal has accentuated these efforts. A summary and evaluation of published information on this subject, with about fifty references, has been prepared by M. E. Sibert and M. A. Steinberg,* who have included some account of the work they have done at Horizons, Inc., Cleveland, U.S.A. The paper refers only to the electrolysis of titanium compounds in fused salt media. Aqueous and organic electrolytes are known to be useless as a source for metallic titanium. Three types of processes were discussed: electrolysis of titanium oxide dissolved in molten alkaline earth halides, electrolysis of titanium halides, and soluble anode procedures. It was considered unlikely that pure titanium could be produced by the oxide process. This was also the experience of the Australian investigators, H. W. Worner and G. D. Cordner. There was a possibility, however, that this process might be utilised to provide the starting material for a refining process. Numerous patents have been granted for processes involving the electrolysis of the halides. These vary greatly in composition of the electrolyte, temperature of operation and kind of cell used. Tetravalent titanium chloride or fluoride in alkali chloride or fluoride melts have most commonly been used, the temperature of operation being about 800 deg. Cent. and several kinds of cell are illustrated in the paper. Cordner and Worner obtained successful titanium deposition from a melt containing trivalent titanium chloride, $TiCl_3$, in a eutectic mixture of potassium and lithium chlorides under hydrogen at 550 deg. Cent. This process, however, owing to its low efficiency, was not readily adaptable to commercial use. Several of the halide processes have reached the pilot plant stage. In the soluble anode processes low-grade titanium may be employed as an anode in a titanium-bearing melt and deposited in purified form at the cathode. Such a process might be capable of a high degree of refining on a continuous basis.

The success of any process will be governed by the quality and net cost of the product. On the basis of present costs, neither $TiCl_4$ nor K_2TiF_6 (in many ways the most promising electrolyte) would be attractive as a starting material unless substantial reductions could be made in the cost of processing. It was considered possible that in an efficient electrolytic process a sufficiently economical operation could be achieved to offset the cost of materials.

Silicon Carbide

AN improved silicon carbide for high-temperature parts is described by K. M. Taylor, of the Carborundum Company, in *Materials and Methods*, October, 1956, page 92. Hitherto limitations of silicon carbide have been related to the bonding material employed, whether a silicate, silicon nitride or silicon. This applies particularly to high-temperature properties. KT silicon carbide is a dense self-bonded material containing up to 98 per cent of silicon carbide. This material, with its higher flexural strength, greater stiffness, lower permeability, better thermal properties and higher resistance to abrasion, is likely to have high-temperature applications as well as those common to other forms of silicon carbide. Its abrasion resistance is from two to four times better than that of silicate—or silicon-nitride-bonded silicon carbide. It is resistant to oxidation and to various corrosive acids. After being heated for sixty hours in air at 1200 deg. Cent. the nitride-bonded carbide gained in weight 3·65 mg per square centimetre, whilst the KT fine grit gained only 0·52 mg per square centimetre. No loss of weight resulted from seven days' immersion in 1 : 4 aqueous solution of H_2SO_4, HNO_3 or HCl, but transverse strength dropped about 6 per cent. In HF of similar concentration there was a loss in weight of 0·4 per cent, and in strength of 2·4 per cent. The new material is not yet in full commercial supply, but is available in limited quantities for development testing.

* *Iron Age*, October 4, 1956, page 98; October 11, page 102.

† *Journal of Metals*, October, 1956, page 1263.

* *Journal of Metals*, September, 1956, page 1162.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

HEAT TRANSFER TO A FLUID FLOWING IN A TUBE WITHIN A RADIATING ENCLOSURE

SIR,—In connection with the design of a small-scale tubular steam generator for laboratory purposes, the problem arose of determining the length of tube necessary for a given total heat transfer per unit time. The steam is carried in tubing having very thick walls and heated electrically by a wire-wound radiating muffle. It was found possible to reduce the problem to the graphical integration of a simple general expression ; the derivation of this expression, though simple, does not appear to have been given previously and is therefore presented here. It is of interest to note that the heat transfer conditions lead to an expression for an optimum tube diameter, though the numerical values are such that this is of little practical interest except perhaps in some special cases.

1. THE HEAT TRANSFER RELATIONSHIP

The tube carrying the fluid is enclosed by a concentric cylindrical radiating enclosure of radius a_w, whose wall has the absolute temperature T_w. The external and internal radii of the tube are a and a_i respectively and the corresponding temperatures (in degrees absolute) T and T_i. The mass flow of the fluid is m and its bulk temperature T_f.

We assume, as will always be true if the tube is designed for a given pressure in the fluid, that

$$\frac{a}{a_i}=\rho, \text{ a constant} \quad . \quad . \quad . \quad . \quad (1).$$

The heat transferred from the tube wall to the fluid per unit mass and per unit length of tube is

$$q=\frac{2\pi a/\rho}{m}\cdot\alpha(T_i-T_f) \quad . \quad . \quad . \quad (2),$$

in which α is the surface transfer coefficient between the tube wall and the fluid. In the steady state this is equal to the heat conducted across the tube wall, i.e.

$$q=\frac{2\pi\lambda}{m\ln\rho}(T-T_i) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

in which λ is the thermal conductivity of the material of the tube.

Eliminating T_i between (2) and (3) gives

$$T=\frac{mq}{2\pi}\left(\frac{\rho}{a\alpha}+\frac{\ln\rho}{\lambda}\right)+T_f \quad . \quad . \quad . \quad (4).$$

Writing, as is customary,

$$\frac{1}{h}=\frac{\rho}{a\alpha}+\frac{\ln\rho}{\lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

(4) becomes

$$T=\frac{mq}{2\pi h}+T_f \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

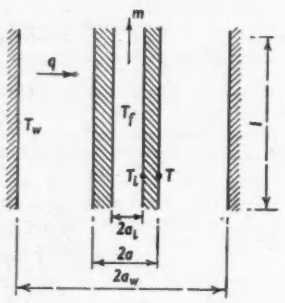
Now in the steady state mq must also equal the heat absorbed by the tube from the radiating muffle. Thus

$$mq=2\pi a\varepsilon_{12}\sigma(T_w^4-T^4) \quad . \quad . \quad . \quad (7),$$

in which σ is the black body constant and ε_{12} is an emissivity-geometric factor having the known form*

$$\varepsilon_{12}=\frac{1}{\frac{1}{\varepsilon_1}+\frac{a}{a_w}\left(\frac{1}{\varepsilon_2}-1\right)} \quad . \quad . \quad . \quad (8),$$

in which ε_1 and ε_2 are the emissivities of the tube and muffle respectively.



If, as will generally be the case, T does not differ greatly from T_f, we can write from (6)

$$T^4=T_f^4\left(1+\frac{mq}{2\pi hT_f}\right)^4\doteq T_f^4\left(1+\frac{2mq}{\pi hT_f}\right). \quad (9).$$

With this approximation (7) may then be written

$$T_w^4-T_f^4=\frac{mq}{\pi}\cdot\frac{h+4\sigma\varepsilon_{12}aT_f^3}{2\sigma\varepsilon_{12}ah}$$

or

$$q=\frac{2\pi\sigma\varepsilon_{12}ah}{m(h+4\sigma\varepsilon_{12}aT_f^3)}(T_w^4-T_f^4). \quad (10).$$

This is the relation for heat transfer to the fluid under the given conditions, provided $\frac{mq}{2\pi hT_f}$ is small in relation to unity.

2. TUBE LENGTH FOR A FIXED DIAMETER

If Q is the total quantity of heat to be transferred to the fluid then

$$q=\frac{1}{m}\cdot\frac{dQ}{dl}=\frac{C_p dT_f}{dl}$$

where C_p is the specific heat of the fluid and l is the length of tube required, the diameter being regarded as fixed.

Substituting this expression in (10) with the abbreviation $K=4\sigma\varepsilon_{12}a$ we get

$$dl=\frac{2mC_p(h+KT_f^3)}{\pi Kh(T_w^4-T_f^4)}dT_f \quad . \quad . \quad . \quad (11)$$

and on integrating between the inlet and outlet temperatures of the fluid we obtain the length of tube required. In performing this integration it is to be noted that C_p and h, the latter being a function of α and λ, will in general be functions of T_f ; usually, therefore, the integration will require to be performed numerically or graphically. If, however: (*a*) the temperature rise ΔT_f of the fluid is small; (*b*) h and C_p may be considered constant; and (*c*) $T_f \ll T_w$ we obtain the following approximate relation for l :

$$l=\frac{2mC_p}{\pi KhT_w^4}(h+K\overline{T_f}^3)\Delta T_f \quad . \quad . \quad (12)$$

in which $\overline{T}_f$ is the mean temperature of the fluid. While of restricted validity, this equation will suffice in many cases for the purpose of preliminary design.

3. THE OPTIMUM TUBE DIAMETER

If we define the optimum tube diameter as that which, for a given mass flow, will result in the greatest amount of heat being transferred to the fluid per unit length of tube, then it is of interest to note that (10) leads to a finite solution.

For present purposes (10) is most conveniently written in the form :

$$\frac{2\pi\sigma}{mq}(T_w^4-T_f^4)=\frac{1}{\varepsilon_{12}a}+\frac{4\sigma T_f^3}{h}$$

which on differentiating gives

$$-\frac{2\pi\sigma}{mq^2}(T_w^4-T_f^4)\frac{dq}{da}=\frac{d}{da}\left(\frac{1}{\varepsilon_{12}a}\right)+4\sigma T_f^3\cdot\frac{d}{da}\left(\frac{1}{h}\right)$$

$$. \quad . \quad . \quad . \quad . \quad (13).$$

Since the coefficient of $\frac{dq}{da}$ is, by hypothesis, finite the condition for an extremum is

$$d\left(\frac{1}{\varepsilon_{12}a}\right)=-4\sigma T_f^3 d\left(\frac{1}{h}\right). \quad . \quad . \quad (14).$$

Now if we write the usual (empirical) equation for convective heat transfer in turbulent flow in the form

$$\frac{\alpha 2a}{\lambda_f}=k\left(\frac{2m}{\pi\eta_f a}\right)^p Pr^q \quad . \quad . \quad . \quad (15)$$

or

$$\alpha=\frac{\beta}{a^{p+1}} \quad . \quad . \quad . \quad . \quad . \quad (16),$$

in which β is a constant with respect to a, substitute (16) in (5) and differentiate, we get

$$\frac{d}{da}\left(\frac{1}{h}\right)=\frac{p\rho a^{p-1}}{\beta} \quad . \quad . \quad . \quad . \quad (17)$$

Also, on multiplying (8) by a, inverting and differentiating we obtain

$$\frac{d}{da}\left(\frac{1}{a\varepsilon_{12}}\right)=-\frac{1}{a^2\varepsilon_1} \quad . \quad . \quad . \quad . \quad (18).$$

On substituting these two expressions in (14) and solving for a there results (writing a_m to indicate an extremum)

$$a_m=\left(\frac{\beta}{4p\sigma T_f^3\rho\varepsilon_1}\right)^{\frac{1}{p+1}}$$

and on substituting the value of β we have the condition that

$$a_m=\left\{2^{p-3}\cdot\frac{k\lambda_f}{p\sigma T_f^3\rho\varepsilon_1}\left(\frac{m}{\pi\eta}\right)^p\cdot Pr^q\right\}^{\frac{1}{p+1}} \quad . \quad (19)$$

for an extremum, which is a maximum. It is interesting to note that according to this equation the optimum radius of the tube is independent of the dimensions and properties of the enclosure. It is also indepen-

*See e.g. Grober, Erk and Grigull, Wärmeübertragung, Berlin (1955).

dent of the thermal conductivity of the tube.

As has been mentioned, it is found on the substitution of numerical values that normally the optimum diameter appears to be too large to be of much practical value. In special cases, however (for example, thin-walled ductwork containing a flowing gas at a high temperature) the equation may have some interest. This is particularly true in the reverse case to that considered, i.e. heat transfer to the surroundings, when equation (19) represents a minimum condition and hence a_m is the external radius of duct which will result in a minimum heat loss by radiation to the surroundings.

C. D. WEIR

University of Glasgow.
November 23, 1956.

"NEVER BE SHORT OF LABOUR"

SIR,—Perhaps you would permit me to reply to Mr. Perrin's objections to my argument (November 16 issue). Wage agreements tied to the cost of living index, the Ministry of Labour informs me, affect between 2,000,000 and 3,000,000 wage earners —not, in my opinion, a sufficiently high proportion of the total to invalidate my argument. It is doubtful, too, whether all these agreements provide for automatic wage reduction, as well as increase, with the cost of living. Mr. Perrin's second statement, that "directly goods are cheap and plentiful, this gives rise to inflation . . . " is, I believe, in contradiction to every tenet of economics. If inflation means anything, it means that goods are few and expensive.

Finally, whether or not the Government of the day decides to control a larger share of the national income by means of increased taxation does not affect my argument. Taxes, of course, return to us through Government spending: only inefficient expenditure—like all other waste—robs the nation of its prosperity. Using the metaphor of my previous letter, the dog then gets too large a share of the national "cake."

E. G. SEMLER

Editor, *Automation Progress*.
November 23, 1956.

Literature

Mechanical Vibrations. By J. P. DEN HARTOG. Fourth edition. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 67s. 6d.

IT is always a pleasure to see a new edition of a well-known book and particularly so when the author is still actively practising the subject about which he has written. The earlier editions stood out from amongst other books on the same subject by the full discussion of many practical examples with which Den Hartog has been associated. The new edition is therefore of considerable interest, as it embodies some of the problems he has had to deal with during the last ten years.

The conception of the book and the layout has remained the same. It aims to give a reasonably complete treatment of the theory of vibrations and is to be used primarily as a textbook for a university first degree, although much advanced material is given for use in post-graduate courses. The practising engineer will find the book very useful as a source of reference, but not, however, as a reference source. This is much regretted. It is agreed that the original literature source need not be quoted in every instance in a textbook and an omission of acknowledgment need offend no one; on the contrary, it should be regarded as a compliment to find one's contributions to the subject treated as standard matter in a textbook. Where particular examples from practice are dealt with, however, a list of references would seem justified for the practising engineer to consult for details of the case, which cannot always be dealt with fully in a book of this nature. This omission of references is all the more surprising by what Den Hartog himself states in the preface: "that in 1934 (when the book was first published) it could be said that the book covered more or less what was known and technically important, no such claim can be made for this fourth edition."

Simple one degree of freedom theory is dealt with fully in the second chapter, the vector method for presentation of relative forces being used wherever appropriate. The extension of this theory to two degrees of freedom is commenced in Chapter 3, but is turned very soon into a very complete analysis of the dynamic vibration absorber, including damping, which is not the elementary or easy subject-matter one would expect to find at this stage in the development of the treatise. Continuous systems and systems with many degrees of freedom are given a concise but adequate treatment in Chapter 4. The mathematics has been kept simple, no use having been made of the Lagrangian equations, and although this may show a certain lack of mathematical elegance it is certainly the right method of approach in a first degree textbook. Problems associated with rotating machinery and multi-cylinder engines are dealt with very fully. It is interesting to note that the property of stress-strain hysteresis is first introduced when whirling of shafts is discussed (in the chapter on Self-Excited Vibrations) and not as a possible contribution to damping in any system in one of the earlier chapters. The book as a whole might be regarded as rather unsystematic; for instance, some sections on vibration measuring instruments are included in the second chapter, in which the foundations of the subject are laid.

Some of the specific cases discussed in detail are the vibration of helicopter rotors, turbine wheels and blades, diesel engine fuel injection valves, wheel shimmy and aeroplane wing flutter. One of the new sections discusses how the Karman vortices can act as an aerodynamic disturbing force and not only on parts of an aeroplane, but also on stationary objects exposed to wind forces. It is offered as an explanation for the failure of the famous Tacoma Narrows bridge in 1940.

The number of exercises, with answers, has been increased to 230. An appendix giving a collection of formulae has been added, and this is indeed useful, although perhaps slightly dangerous if used by the uninitiated without knowledge of the assumptions made in the derivation of these formulæ. The book is well produced with many clear illustrations. The subject index seems rather brief for a work with so many different topics.

Electricity, Magnetism and Atomic Physics. Volume I; Electricity and Magnetism. By J. H. FEWKES and J. YARWOOD. University Tutorial Press, Ltd., Clifton House, Euston Road, London, N.W.1. Price 36s.

THIS volume is intended to cover relevant parts of the B.Sc. General and Part I of the B.Sc. Special Degrees in Physics of the University of London, and of Part I of the Natural Sciences Tripos of the University of Cambridge. Some of the material covers certain aspects of the Part II requirements, and a few of the sections on electronics and radio communications are somewhat beyond the scope of most first degrees. Advanced level in the General Certificate of Education is a necessary prerequisite.

The book is comprehensive in scope and a special feature is the detailed description of experimental techniques to illustrate the basic theory. This must be regarded as important in view of the rapid strides which have been made in electrical technology during the past decade. Electronics is given a prominent place in the text and the bias here is essentially from the standpoint of practical circuit techniques. Again, in radio communications an introduction to modern ideas is presented and illustrated with practical circuits, whilst the chapters on electrons in gases and the emission of electrons from solids, give a well-balanced introduction to these important aspects of modern physics. Much of the material is also required by honours students in electrical engineering but the book is, nevertheless, not recommended as a suitable text because of the somewhat superficial treatment of the fundamental theory of electrostatics and electromagnetism. Moreover, the method of introducing the operator j is not convincing and the subsequent definition of vector impedance as the ratio of instantaneous e.m.f. to instantaneous current is not recommended—in the same chapter the definition of impedance is given in the conventional way in terms of peak values of e.m.f. and current. There are many misprints in the book, noteworthy among which are the errors in Figs. 2 and 6; the error in Fig. 80 (*a*) is likely to cause considerable difficulty to the less enlightened student.

Although the book undoubtedly has several attractive features, it is felt that the inadequate basic theory of electricity and magnetism coupled with the not too rigorous treatment of a.c. circuits is an undesirable feature.

Aeronautical History in Pictures. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 2s.

THE Science Museum has prepared this booklet, which comprises sixty-six pictures of aerostats and aerodynes, together with some brief comments on their place in history. The subjects are principally British, except when illustrating the pioneer balloon flights, the earliest manned powered aeroplanes, the first flight of the gas turbine, and modern transport aircraft. Surprisingly, the rocket craft that first broke the "sound barrier" and exceeded Mach 2 at the end of the first fifty years of heavier-than-air flight are omitted; the only picture of a supersonic aircraft is particularly unrevealing. A spectacular shot of four booster motors separating from a test vehicle is perhaps misleadingly captioned, "Early British guided missile." Impressive is a magnificent study of an Avro Canada "CF-100" towering on a column of smoke at the culmination of a rocket-assisted take-off.

Books Received

Laboratory Administration. By E. S. Hiscocks. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 36s.

Bridging the Years. By C. M. Norrie. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 21s.

Instrument Technology. Volume II. By E. B. Jones. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 40s.

Machinery at the Smithfield Show

No. I

DURING the first week of December, there is held annually at Earls Court, the Smithfield Show and Agricultural Machinery Exhibition. The show has a long history, for the first exhibition or meeting of its kind to be arranged by the Smithfield Club took place in 1798. Through the years the show has been staged in various halls in London, and although up to the time of the second world war, it was generally regarded as the "Christmas fat stock show," for more than a century a large portion of the exhibition space has regularly been devoted to a display of agricultural implements and machinery, together with the varied equipment used in the meat trades.

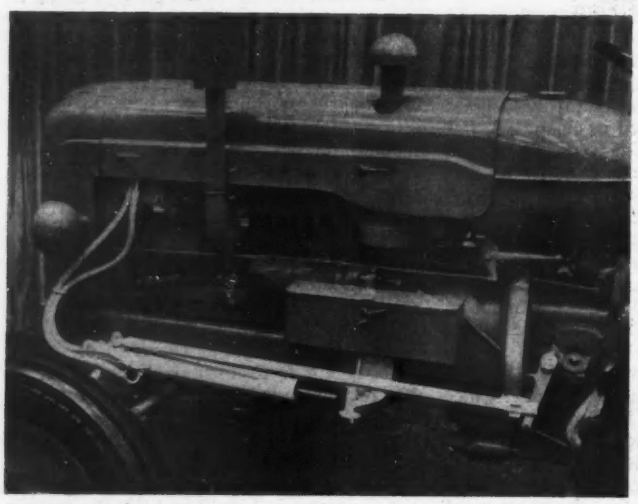


Fig. 1—Arrangement of the power-assisted steering system for the Fordson "Major" tractor

When, after a break caused by the war, the Smithfield Show was resumed in 1949, the organisation was undertaken by a joint committee appointed by the Smithfield Club, the Agricultural Engineers' Association, and the Society of Motor Manufacturers and Traders. The "Smithfield" still retains some of its traditional characteristics ; the exhibit of cattle, sheep and pigs is always impressive and forms a part of the show which undoubtedly attracts farmers and meat traders from all over this country and from many countries overseas. But by far the greater portion of the space available at Earls Court is occupied by the trade stands on which are shown the products of the agricultural machinery industry. This year's Smithfield Show, which will begin on Monday next, December 3 and continue until Friday, December 7, is the eighth to be organised by the joint committee, and there is little doubt that, important as the 1500 or so livestock exhibits are as representing the excellence of British farming produce, the emphasis will be on the machinery and implements designed to improve the productivity of the world's agriculture.

The Agricultural Engineers' Association has recently made a statement about trends in the production and sales of British tractors and agricultural machinery. This shows that during September the total output of tractors and machinery together was slightly higher than in September last year. The increase, however, was accounted for by higher tractor production than in some of the earlier months of this year ; output of farm implements in September was lower than in August. Again, compared with the earlier months of this year, there was some improvement in September in home sales of tractors, though a similar trend was not evident in home sales of machinery and implements. The credit squeeze has, of course, affected home business in this as in other sectors of the engineering industry. Nevertheless, the Association takes the view that there is not likely to be any further deterioration in the home market, and it goes so far as to suggest that, when the figures become available, they will reveal that the general level of sales during the final quarter of this year will have equalled that reached in the comparable period of last year. Export sales of tractors and agricultural machinery last year amounted to just over £66,000,000. This year, they have declined a little, though in the first ten months an export sales figure of just under £53,000,000 was achieved, compared with £57,000,000 in the corresponding period of last year.

The continuing importance of exports was emphasised last week by Sir William Rootes, who is the chairman of the Smithfield Show joint committee and chairman of the Dollar Exports Council. At Earls Court next week, he said, there would be exhibited machinery which was being exported to most parts of the world in quantities which represented a great contribution to the currency situation of the United Kingdom. A study of the advance information about the exhibits indicates that the Smithfield Show is again providing the occasion for manufacturers to introduce new machinery developments and improvements. The number of new designs may not be so great as in former years, but the machinery display, taken as a whole, unquestionably shows that agricultural engineers remain keenly aware of the need to maintain a high technical standard and a consequential high factor of operational efficiency.

Tractor Developments

In this general survey of the machinery section of the Smithfield Show we begin with the tractors, the progressive development of which has been the prime factor in the growth of mechanised agriculture. There will be some tractors which will be new to the Smithfield Show, having come into production during the past twelve months. The range of tractors, wheeled and crawler, which is now available for agricultural and horticultural tasks and also for all kinds of civil engineering work, is extensive. Recent developments have included improvements in power take-off and hydraulic lift systems ; they are improvements which aim at increased operating efficiency and a high degree of safety at work.

One example of this kind is to be shown by the Ford Motor Company, Ltd., Dagenham, Essex. From early in the New Year three refinements in the design of the Fordson "Major" tractor will be available. The first of these developments is an adaptation of the tractor to take a new double clutch assembly, giving live power take-off and hydraulics. There are two separate discs transmitting power by way of independent drive shafts, one operating within the other. The inner (solid) shaft connects with the gearbox and rear wheels of the tractor, and the outer (hollow) shaft with the power take-off and the hydraulic pump. When the clutch pedal is depressed to half-way along its travel, the transmission clutch disengages and the engine and wheels are disconnected in the conventional way ; the power take-off shaft, however, continues to rotate until the pedal is fully down. Gear changing can thus be accomplished without stopping the power take-off, and only complete depression of the clutch pedal allows the engine to idle. As already mentioned, the hollow drive shaft transmits power to the hydraulic lift pump. A "live" hydraulic system is particularly useful in the operation of such implements as loaders and graders. It becomes possible, for example, to vary the height of dozer and grader blades exactly in accordance with the resistance being met, while at the same time altering the speed of the tractor.

The double clutch assembly is strongly made so that all the power of the engine can be absorbed through either the transmission or the power take-off clutch. The discs themselves are of hardened steel and are arcuate in construction. Each disc is balanced to within half an ounce, is 12in in diameter and presents a total friction area of 126 square inches. The clutch pressure plates, which are also balanced to within the same limits, are made of cast iron, twelve springs on each plate providing the requisite friction pressure. The advantage of a live power take-off is that it permits the operation of tractor-driven implements at a constant speed whatever land speed is being transmitted through the gears. This means that when, say, a combine harvester is clogging through overloading, the driver can adjust his land speed to the crop intake without stopping the cylinder.

The second refinement which is being applied

Fig. 2—David Brown "900" diesel-engined tractor. It is rated at 40 b.h.p.

to the Fordson "Major" is a power-assisted steering assembly, comprising a front-mounted oil reservoir and a pump driven by a vee-belt from the crankshaft pulley. The pump delivers 2 gallons of oil a minute at 400 lb operating pressure. This oil powers a double-acting ram which incorporates a shuttle valve to direct the flow of oil as required. A relief valve is provided which blows off at 750 lb pressure, and a spring-loaded flow control valve is also incorporated in a bore in the front cover of the pump to limit output to approximately 2·5 gallons per minute. The pump, incidentally, has been designed to provide power assistance for steering even when the engine is idling and the pump operating at minimum output. Slight movement of the steering wheel is conducted by the steering drop arm and through the drag link to the shuttle valve assembly. This valve is sensitive and very little movement is sufficient to allow oil from the pump to feed into the appropriate side of the ram. The ram then operates the steering spindle arm turning the tractor wheels. When the tractor is being driven straight ahead, the shuttle valve spool is held in the centre or neutral position. In this position, oil from the pump flows by the valve spool lands and returns to the reservoir through the port in the shuttle valve housing. When the steering wheel is first turned to the right, the steering drag link exerts a force on the shuttle valve which moves the spool to the rear. When the spool is in this position the oil passage leading to the piston end of the power cylinder is closed to pump pressure, but is open to the reservoir. The passage leading to the piston rod end of the cylinder is open to pump pressure. As the oil from the pump flows into the power cylinder, the pressure increases until it is sufficient to force the cylinder and the steering spindle arm to the rear, thus providing the power assistance for the right turn. The oil displaced from the front end of the power cylinder flows back through the shuttle valve to the oil reservoir. When pressure on the steering wheel stops, the shuttle valve spool is returned by the spring to the neutral position and power assistance ceases, keeping the tractor wheels in the direction required. When making a left turn, the steering drag link moves the shuttle valve spool forward. The movement of the valve spool opens the pressure supply passage in the valve housing which leads to the piston end of the power cylinder. As the pressure in the power cylinder increases, the cylinder and the steering spindle arm move forward, providing the power assistance for the left turn. The oil displaced from the piston rod end of the power cylinder flows back through the shuttle valve to the oil reservoir. When pressure on the steering wheel stops, the shuttle valve spool is again returned to the neutral position and power assistance ceases. Normal manual steering is immediately effective if the engine is stalled or switched off. The arrangement of the power-assisted steering assembly is indicated in Fig. 1.

Another Fordson introduction is one which is designed to provide tractor drivers with greater comfort and ease of operation. It is a "New-Comfort" tractor seat provided with a foam rubber cushion and a back rest. As well as tipping forward, the seat can be moved 10in backwards to enable the driver to take up a free standing position if he wishes. This movement is achieved by the action of two hinged links attached to the front end of the seat pan. A spring-loaded safety catch is provided to ensure that the seat is positively locked when it is returned to the normal driving position.

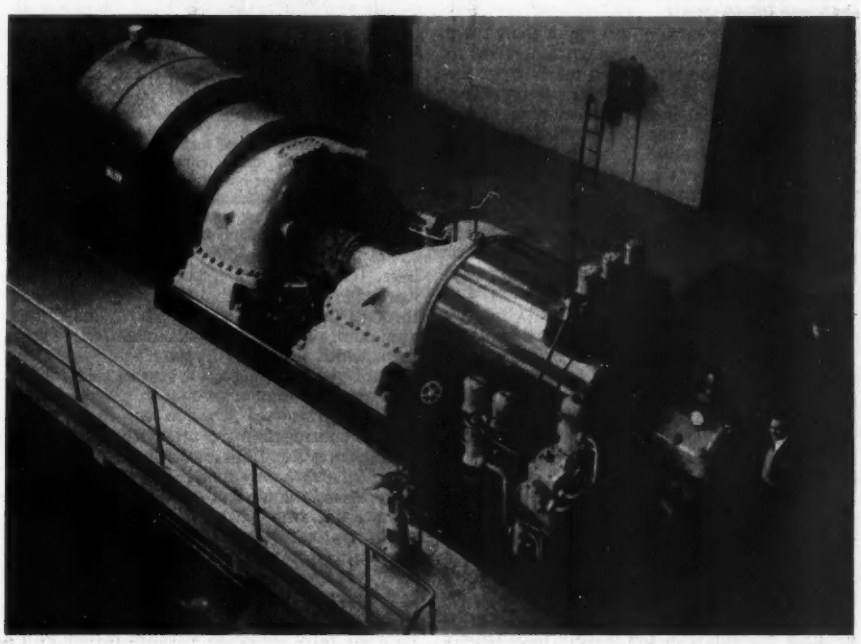
One of the newly-introduced tractors to be shown at Earls Court is the "900," which has been added to the series produced by David Brown Industries, Ltd., Meltham, Huddersfield. In 1953, this firm introduced its "30D" diesel-engined, wheeled tractor, which gives about 34 b.h.p. The "900" tractor (Fig. 2) is stated to be an up-to-date development of the "30D," the engine power having been increased to 40 b.h.p. In addition to this greater engine power the transmission differs from that of the new tractor's predecessor. The final gear reduction has been increased, and the engine transmission is centralised between the wheels so that wheel adjustment is simplified. Another change is in the employment of an adjustable sliding front axle, permitting wheel settings from 52in to 76in in 4in steps. The track rod is placed behind the axle for protection and is split to enable track adjustment to be made through a centrally mounted double lever. The "900" tractor is equipped with the David Brown traction control unit, which was described in THE ENGINEER, December 10, 1954. The primary purpose of this device is to eliminate wheel slip without the aid of wheel weights, ballast and similar arrangements. By the aid of traction control a progressively varying proportion of implement weight is transferred to the tractor's rear wheels.

(To be concluded)

Axial Blast-Furnace Blower

An axial blast-furnace blower driven by a condensing steam turbine has been installed at the Port Talbot works of the Steel Company of Wales, Ltd., by Sulzer Brothers, Ltd. The installation supplies air to a furnace for which the pressure and quantity of the blast required at present are well below the designed maximum. Particulars have been received from Sulzer Brothers (London), Ltd., of the way in which the turbine and blower have been arranged to satisfy present demands with provision for the ultimate requirements.

AT the end of 1955, the Steel Company of Wales, Ltd., put into commission at the Port Talbot works in South Wales one of the largest blast-furnaces in the world, with a hearth diameter of 29ft 9in. In connection with this new furnace a new power-house has been built containing a single blower group and an alternator set. The blower set, which is illustrated on this page, consists of a Sulzer axial flow blower with a maximum capacity of 140,000 cubic feet per minute at 35 lb per square inch, driven by a turbine with a maximum power output of 12,000kW. Steam for the blower turbine and the turbo-alternator is supplied by a boiler fired by blast-furnace and coke-oven gas, and designed to produce 100 tons per hour of steam at a pressure of 625 lb per square inch and a temperature of 875 deg. Fah. The new furnace has been designed for an ultimate service with top pressure, but this will only be required in a few years' time, so that pressure and quantity of the blast at present are well below the designed maximum of the set. The blower specification consequently called for working points covering a wide range which, by the use of a steam turbine drive with variable speed, could be covered without the need for any further regulating equipment such as throttling or the like at the blower. On the turbine side the problem was considerably more difficult as the power output required for normal working was well below the maximum of which the turbine must be capable. The problems involved were discussed in some detail in an article on April 13 last (page 336): in this case, these conditions have been met by a special Oerlikon arrangement of the steam admission governing valves on the turbine, which are referred to in detail below. It is pointed out that generally the relatively steep pressure-volume characteristic of an axial design blower as compared with the flatter characteristic of the radial construction is favourable for blast-furnace service as there is always a pressure reserve available in the case of a blocked furnace. In addition, it is usual to work the furnaces at constant volume, and with the steeper characteristic this entails less change of speed for different working points. Furthermore there is claimed the advantage of an inherently high efficiency in axial blowers.



Turbine-driven axial blower set for large blast-furnace. This blower has a maximum capacity of 140,000 cubic feet per minute at 35 lb per square inch

The blower installed at Port Talbot is one of normal Sulzer design, with twelve stages. It consists in principle of a cast iron casing which is horizontally divided at shaft level with the suction and delivery branch on the bottom half. The stationary blading is carried in a separate blade support, which is centred in the casing, but free to expand during service and when warming up. The rotor carried in two plain pressure-lubricated bearings is a solid forging and the runner blades are fixed in circumferential fir-tree root slots. The Oerlikon impulse steam turbine driving the blower has fourteen stages. The high-pressure and the low-pressure casings are bolted together vertically and the low-pressure side is connected by a flexible expansion

piece to the condenser. The performance characteristics of the set can be seen in the accompanying graph.

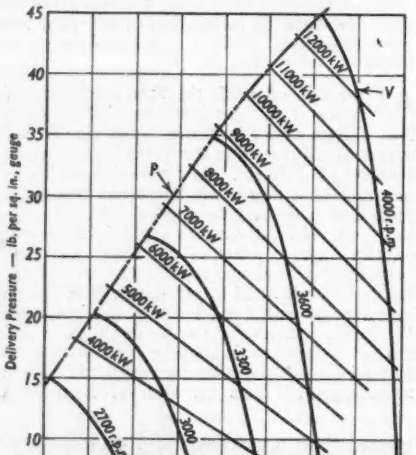
A common lubricating oil system serving the complete set comprises two main pumps, working in parallel, and driven mechanically from the turbine shaft. These pumps draw oil from the tank and pass it through magnetic filters to the hydraulic regulating system, and through mechanical filters and oil coolers to the bearings. For use during the starting-up and shutting-down of the plant, and in cases of emergency or if the main pumps fail, two further auxiliary pumps are provided, one driven by an a.c. electric motor and the other by a small turbine. The surface condenser uses water from a closed circuit with a cooling tower, which receives make-up water from the docks. Two condensate extraction pumps are provided, one being driven by an electric motor and the other by a back-pressure steam turbine. Steam jet, two-stage air ejectors for the condenser utilise the condensate in their condensers.

In view of the service requirements two basic forms of regulation for the blower set are provided, and they comprise constant-blast volume and constant-speed regulation. In addition, the turbine has the usual overspeed safety trip and the blower is safeguarded by an automatic anti-surge device. The regulating gear consists of a hydraulic turbine speed governor and two Reavell-Askania jet pipe units, one for the constant volume and the other for the anti-surge control. The centrifugal fly-weight Oerlikon speed governor, by means of a piston valve, adjusts a regulating oil pressure as a function of the speed. This pressure in its turn actuates a pilot valve which governs the oil supply to the common servo-motor for the steam admission valves of the turbine. The servo-motor is mechanically connected to the valves by a camshaft and levers.

For constant volume governing of the blower a pressure differential impulse corresponding to the aspirated volume of air is taken from the blower intake to the volume regulator. This pressure differential moves the jet pipe of the Askania gear and the resulting oil pressure opens or closes a leak-off valve situated in the regulating oil pressure line from the turbine speed governor. This leak-off valve can influence the pressure and therefore the setting of the steam admission valves irrespective of the setting of the speed governor. The system is such that the governor acts as an upper speed limit when the set is running on constant volume regulation and vice versa.

The steam admission arrangement of the turbine includes a main stop and emergency valve, which can be tripped by the overspeed device, by hand, and automatically in case of failing oil pressure. Two-part load governing valves supply steam to two partial-admission nozzle boxes of the first stage and cover the minimum to normal output range of the turbine. These two valves, together with the main valve, are built into a separate steam chest which is placed next to the turbine on the high-pressure side. In order to deal with the maximum output required three additional overload valves are provided, and they are mounted directly on the high-pressure casing. As previously mentioned, the working conditions of the blast-furnace require at most times a power output of only approximately 70 per cent of the maximum the turbine must be capable of, so that the efficiency at this point must be high. If the turbine nozzles were laid out and dimensioned to suit this requirement the specific steam consumption at full load would suffer if the classic mode of steam admission were used, and, furthermore, it might be difficult to obtain the required overload. The system used consists of a special overload channel in the first partial admission stages, which is controlled by the first two overload valves. The first of these valves admits steam into the first stage, from which it is bled off again and passed through the second valve into the third stage. With this system the steam flow through the overload channels can be completely shut off for normal load so that there is no disturbance of the normal steam flow and therefore no additional losses. On the other hand, the overload steam is expanded in two stages down to the pressure after the third turbine stage, this pressure in itself being higher on overload owing to the increased steam flow through the following stages. The additional quantity of steam required is, however, relatively small, as it can already do useful work in the first stage and not only in the third and following stages. Measurements on turbines equipped with this form of overload control have shown that the efficiency even increases slightly for maximum output and remains almost constant over a large working range.

In order to protect the blower against abnormal working conditions of low volume and high pressure, such as might for example occur if the stop valve in the delivery main was inadvertently closed, an automatic anti-surge device has been provided. This device consists in principle of a blow-off valve in the delivery main which is



Working characteristics of turbine-driven axial blower with regulation by speed adjustment. The pressure/volume curves V show how the delivery can be adapted to the blast requirements by adjusting the speed. The corresponding input can be read off the power curves. The surging limit of the set is shown by the chain-dotted curve P

worked in such a way that the air volume passing through the blower is kept above the critical minimum. The Reavell-Askania anti-surge regulator, which works on the same principles as the contant volume regulator mentioned above, receives two impulses—one from the blower intake volume (the same as for the constant volume control) and the other from the blower delivery pressure. These two impulses are combined in such a way that the blow-off curve on the pressure volume characteristic of the blower, i.e. the line where the blow-off valve starts to open, approximates to the surge line which is theoretically a parabolic curve. The variable oil pressure from the regulator operates the hydraulic servo-motor of the blow-off valve through a built-on pilot valve. The double-seat blow-off valve combines sensitive action with a positive air seal when in the closed position. In addition, manual operation of the blow-off is provided, so that it can be kept permanently open when necessary.

All main controls for the turbo set and also the principal indicating and, where required, recording instruments, are situated on an instrument panel which is arranged back to back with the boiler panel, close to the high-pressure pedestal of the steam turbine. This panel contains the remote control setting means for the constant volume regulator, the turbine speed governor and the manual operating means for the blow-off valve. The instruments include a set of steam pressure gauges, showing the individual pressures after the various governing valves and at various stages in the turbine ; the vacuum gauge for the condenser ; the regulating and lubricating oil pressure gauges ; and the air volume and delivery pressure gauges for the blower. In addition, there is a multi-point temperature indicator for various points in the steam, oil and air circuits. The enclosed space between the turbo-blower and the boiler panel is used to house the control gear and the constant volume and anti-surge units, its oil supply being derived from the main circuit of the turbine as already mentioned.

With a blower set of this size, particular care had to be taken in the laying out of the air piping so as to avoid inadmissibly large forces from the pipes reacting on to the blower branches and, therefore, on to the casing. This necessitated the use of expansion pieces for axial, and pipe joints for angular, movement to allow thermal expansion to take place freely with no, or only a small, reaction. Furthermore, the large pipe sizes required for handling the volume of air involved do not allow the use of radiused bends as these would in most cases take up far too much space. Based upon experience of similar plants, Sulzer Brothers, Ltd., undertook the general layout planning of the suction, delivery and blow-off mains and supplied the necessary equipment apart from the pipes. This equipment comprises right-angle bends with built-in guide blade cascades of all-welded design which combine small space requirements with low pressure losses. The necessary kinematic requirements of the mains are covered by the firm's design of pipe joints which work on the Cardan principle and allow angular movement but no axial displacement. By eliminating axial freedom no external forces resulting from pressure arise which would otherwise have to be taken up by special supports. A non-return valve in the blower delivery main is of flap design and is worked directly by the air stream, so that very little obstruction is caused when it is in the open position. The plant has not been equipped with an air filter, but space has been provided so that one can be added later on if this should prove advantageous.

Both the blower and its turbine are directly mounted on a concrete foundation without any common bedplate, as is the firm's general practice, as it is considered that, provided the concrete foundations have been correctly dimensioned and executed, perfectly satisfactory results are obtained. The condenser is installed in the basement and connected to the turbine by a stainless steel expansion piece. The condensate extraction pumps are mounted on the floor, whilst the air ejectors are placed on a separate platform, half-way between basement and machine house floor levels.

Both turbine and blower were delivered to site during the early summer of 1955 and erection was completed in late autumn. Owing to the conditions of the furnace and the rest of the plant no actual testing of the blower group was at that time possible, and the machine was therefore put straight into operation when the furnace was ready, in January, 1956. The set has been running continuously since then, apart from some short stoppages in connection with other equipment. Preliminary measurements have shown that the performance of both the blower and the turbine are up to expectations and it is anticipated that the guarantee figures will be surpassed. The Steel Company of Wales has ordered a second, practically identical, set for the No. 5 furnace, which is scheduled to go into operation by the second half of 1958. Both blower and turbine will be of the same size as for its No. 4 furnace, although the blower will be slightly modified in order to obtain somewhat higher pressures, which experience has shown to be advantageous. It is considered probable that this modification will also be carried out on the existing set, as its design enables the performance to be modified within certain limits without any major alteration.

DITCH CLEANING MACHINERY COMPETITION.—The Royal Agricultural Society has now accepted entries of fifteen machines for its ditch cleaning machinery competition. All these machines are the products of British makers. In the competition, silver and bronze medals are offered for mechanically-operated appliances most suitable for cleaning farm ditches which are accessible from only one side. The competitors are required to demonstrate their machines to the judges on a site of their own choice before the end of this year and, if required, to give a second demonstration on a site selected by the Society. The winning machines will be exhibited at next year's Royal Show, which is to be held at Norwich.

Industrial and Labour Notes

Overseas Trade

The Board of Trade has now published the final figures about the United Kingdom's overseas trading activity in October. It was a longer working month (twenty-eight days) than usual. The value of exports, at £294,900,000, was 14 per cent above the monthly average for the first nine months of this year, and the value of imports, at £354,300,000, was 9·5 per cent higher. Re-exports, at a value of £12,700,000, were higher than in recent months, although they were still below the level reached in the early part of this year.

The Board of Trade says that, taking into account the underlying upward trend of United Kingdom exports, conditions were particularly favourable for a record figure in October. Seasonally, the month is a good one as there is a resumption of full activity after the annual holiday period. The requisitioning of ships in the early stages of the Suez emergency, which slightly reduced export shipments in August and September, did not affect normal loadings and sailings in October, and it is thought that there may, in fact, have been some recovery of shipments previously delayed. But, the Board of Trade asserts, even after allowing for these factors and for the exceptional number of working days, the October figure is still an improvement on the "slightly disappointing" third quarter. At the same time, it has perhaps fallen a little short of a full recovery to the underlying annual rate of increase of 10 per cent which was achieved in the first half of this year.

The figures show that, although nearly all categories of exports increased in October, the rise was for once less marked in engineering products than in other kinds of manufactured goods. In spite of a high figure of £8,500,000 for ships and boats, the total exports of engineering products in October were only 5·5 per cent above the monthly average for the January–September period, compared with the overall increase of 14 per cent. Exports of machinery other than electric approached £44,000,000 in October, which was 4·5 per cent above the monthly rate for January–September. In this group, exports to India, Canada and some European markets continued to rise. Exports of electrical machinery and apparatus rose 7 per cent in October, and here again there were increases in the shipments to India and Canada. The sharp rise in metal exports in October, to a value of over £43,000,000, included increases in all divisions. Non-ferrous metals were 35 per cent above the January–September rate, and iron and steel exports were 20 per cent higher, with increases to Australia, India, Canada and the U.S.A.

British Railways and the Oil Shortage

The British Transport Commission and the regional managements of British Railways have stated that plans have been made for relieving, to the greatest possible extent, the strain which will be imposed on the national transport system by restrictions on oil supplies. The British Transport Commission says that as soon as the first restrictions on oil fuel supplies were announced, railway staffs were alerted to make every effort to deal with extra traffic. Up to the end of last week, however, no heavy diversion of traffic to the railways had occurred.

In the week ended November 17, British Railways moved over 300,000 wagons (more than 3,500,000 tons) of coal from collieries and opencast sites, which was 2200 wagons more than in the comparable week last year. But British Railways have said that they could carry at least a further 400,000 tons a week of the coal that is at present being transported by road.

In general, the aim of British Railways is to introduce more fast freight trains to take traffic now being moved by road between major industrial areas, but the railways have explained that not all the freight trains at present scheduled are fully loaded. There is about 20 per cent spare capacity in such trains on main trunk routes, though not necessarily to the same extent on all routes. It is therefore hoped that industry and transport organisations will co-operate in the development of a scheme for the intensification of feeder services to the freight terminals.

In a statement dealing with these matters, the British Transport Commission says that, although there is a good reserve of unused freight wagons at the moment, British Railways have issued instructions for wagon repairs to be speeded up and for a reduction of unloading time. A general appeal is also made to traders to unload and release wagons as quickly as possible. About passenger traffic, the statement remarks that the staggering of working hours would help considerably to ease the increase peaks caused by the reduction in motor transport. Finally, the statement directs attention to the fact that one matter affecting the ability of British Railways to deal with considerable additional traffic is the shortage of staff in certain localities. The staff position has improved this year and the shortages are not general, yet they could create local difficulties. British Railways say that consultations are taking place with the trade unions with a view to ensuring that all available staff is used as effectively as possible during the present emergency.

Fuel Oil Supplies

Following the statement about petrol rationing, made last week by the Minister of Fuel, the Federation of British Industries commented on the position. It expressed relief that the situation would not compel further cuts in fuel oil, at any rate for some time. The cuts in diesel oil and petrol, the F.B.I. said, would involve an average reduction of something like a third in the road mileage of all vehicles. The industrial problem, it added, would not so much be one of maintaining output as of moving the product both into and out of the works.

To a large extent, the F.B.I. went on to say, the railways would get their "big opportunity." But many of the traffics concerned were not rail problems, and there would be need for much ingenuity. The F.B.I. stated that it had asked the Government to consider carefully the temporary waiving of the restrictions which would otherwise prevent C licence holders from devising pooling arrangements. The F.B.I. also pointed out that, apart from road transport, many industries used gas-diesel oil for several other purposes such as heating furnaces, kilns and ovens, running stationary engines for driving compressors, or circulating pumps, driving portable plant like excavators and hoists, and for driving barges and works locomotives. The F.B.I. suggested that it would be a real puzzle to find out how "to reduce all those uses by an average of 20 per cent without some pretty nasty repercussions." The best way to tackle that problem, it urged, would be by the assessment of individual needs rather than by making a rough cut of 20 per cent for everybody.

British Industries Fair, 1957

Next year, the British Industries Fair is to be held at Castle Bromwich, Birmingham, from May 6 to 17. The financial backing and organisation of the Fair are being undertaken by the Birmingham Chamber of Commerce, following the decision not to hold the Fair in London any more. The Birmingham Chamber of Commerce, it will be remembered, has been running the heavy section of the Fair at Castle Bromwich since 1920.

This week it has been announced that every section of British industry is being invited to participate in next year's Fair, and that a number of the former London exhibitors have indicated their intention to show at Castle Bromwich. Half the available stand space has already been booked. The President of the Board of Trade, Mr. Peter Thorneycroft, has consented to act as honorary president of the Fair. In a letter to the organisers he has commented on the changes in the Fair in recent years; his letter goes on to say that "what remains unchanged is the importance of using the opportunity presented by the British Industries Fair to show the world the vitality and progress of British industry."

The organisers say that invitations have been sent to nearly 140,000 overseas and home buyers inviting them to visit the Fair. More than 100 countries are covered by these invitations and ten languages are being used.

Restrictive Trading Agreements

To-day, November 30, is the beginning of the three-month period during which particulars of many restrictive trading agreements must be sent to the Registrar of Restrictive Trading Agreements for inclusion in the register, which, in due course, will be available for public inspection. The kinds of agreements are defined in an Order made by the Board of Trade on August 2 last, and, broadly, are those dealing with prices, charges or conditions for the supply or processing of goods, or with differentiation between traders or processers.

The particulars required by the Registrar are set out in *Registration of Restrictive Trading Agreements Regulations*, 1956 (H.M. Stationery Office). Broadly, the requirements are four copies of all documents constituting an agreement and four copies of a memorandum containing any part of an agreement which has not hitherto been put into writing. These must be accompanied by a printed form certifying that they contain all the terms of the agreement and all the parties to it. The forms of certificate, and information on which form to use in various cases, can be obtained from the Registrar's offices in London and Edinburgh; the Keeper of the Register in Belfast; all offices of the Federation of British Industries, and branch offices of the National Union of Manufacturers, and from all Chambers of Commerce affiliated to the Association of British Chambers of Commerce.

Iron Castings Production

The Iron and Steel Board has stated that, in the third quarter of this year, the production of iron castings in the United Kingdom totalled 863,950 tons, compared with 879,680 tons in the corresponding period of last year. The Council of Ironfoundry Associations, in some comments on the Board's figures, has pointed out that the third quarter of the year covers the holiday period. This year, the Council says, holidays have been taken later than is customary, a factor which has tended to upset the normal pattern of production.

The full effect of these factors on production is difficult to assess, the Council continues, and in consequence it is likely that the third quarter's statistics for 1956 give a less reliable guide to conditions in the industry than did the statistics for the preceding quarters. For the first three quarters of this year taken together, iron castings production was 1 per cent higher than in the comparable period of 1955. Iron castings output for the engineering section as a whole showed a small reduction in the third quarter this year compared with last, though there continued to be significant increases in the quantities of castings required for machine tools, electrical engineering and iron and steel works plant. Automobile castings production, which had been relatively low in the second quarter of this year, was further depressed in the third. By contrast, the demand for ingot moulds for the steel industry and castings for railway requirements continued to rise during the third quarter. The number of people employed in the ironfounding industry on September 29 was 141,867, a reduction of 2 per cent compared with the labour force at the end of September, 1955.

Swiss Water Power

NEW hydro-electric power stations in Switzerland and extensions of existing installations have brought about an increase of 160MW capacity during the course of last year, according to the 1955 Annual Report of the Schweizerischer Wasserwirtschaftsverband. This constitutes an additional generation in the mean year of about 860 million kWh, of which 460 million kWh or 54 per cent is winter energy. The development of Swiss hydro-electric power since 1930 is outlined in Table IV.

In spite of the new hydro-electric and thermal capacity and imports of electricity during the winter, shortages continued during the winter season of 1955–56. The chief reason was that too many of the hydro-electric stations are still run-of-river stations. Production at the power stations and imports of electricity are shown in Table V.

TABLE I—*Electricity Consumption and Exports (millions kWh)*

Hydro-graphical year	Domestic, artisans, agriculture	Railways		General industry	Chemical, metallurgical and thermal uses	Water heaters	Losses, storage pumps	Inland consumption	Export
		SBB	Others						
1938–39	1,411	549	173	819	1,404	506	751	5,613	1,563
1950–51	3,770	811	261	1,797	2,364	1,024	1,527	11,554	1,099
1951–52	4,086	842	276	1,852	2,540	787	1,665	12,048	1,202
1952–53	4,421	871	287	1,894	2,464	850	1,665	12,452	1,499
1953–54	4,801	887	288	2,075	2,485	599	1,818	12,953	1,424
1954–55	5,101	918	297	2,238	2,790	847	1,873	14,064	2,009

TABLE II—*Swiss Hydro-Electric Power Stations of 450kW or Over, Commissioned in 1955*

Station	Installed capacity, h.p.	Generating capacity, MW	Mean annual generations (millions kWh)		
			Winter (October–March)	Summer (April–September)	Total
Birsfelden (fourth set)	30,000	21	—	—	—
Oberhasli (intake extension)	—	—	+25	+175	+200
Maggia (stage 1) :					
Peccia	65,000	47	67	17	84
Cavergno	75,000	55	111	100	211
Verbano (Sambuco reservoir)	—	—	+41	+6	+47
Ritom (reservoir extension)	—	—	+23·7	—	+23·7
Les Clées	34,500	24	45	44	89
Zervreila :					
Rabiusa–Realta (intake extension)	—	—	+18	+3	+21
Marmorera–Tinzen	—	—	+85	—	+85
Barberine :					
Vieux Emosson (new reservoir)	—	—	+24	−7	+17
Isenthal	12,000	8·6	11·4	31·8	43·2
Muotatal	9,500	7	9	27	36
Total	226,000	162·6	460·1	396·8	856·9

TABLE III—*Hydro-Electric Power Stations Under Construction or Alteration in 1956*

Station	Probable date of commissioning	Installed capacity, h.p.	Generating capacity, MW	Mean generation (millions kWh)		
				October–March	April–September	Total
Laufenburg (extension)	1956	+11,000	+8	+12	+18	+30
Hagneck (fifth set)	1956	+3,900	+2·7	+2	+10	+12
Rheinau	1956	56,000	40	97	118	215
Lavey (third set)	1956–57	+42,000	+30	+30	+100	+130
Aarau (alteration)	1957, 1960	+2,200	+1·5	+6	+15	+21
Alpnach	1957	3,000	2·1	6·6	7·7	14·3
Diablerets (with Arnensee reservoir)	1956–57	6,700	4·7	11·3	—	11·3
Grande Dixence (first stage) :						
Fionnay	1957–60	150,000	105	81	—	81
Nendaz	1957–60	180,000	128	108·5	—	108·5
		330,000	233	189·5	—	189·5
(Additions under construction)	(By 1960)	—	—	(561)	(476)	(1,037)
Lienne :						
Croix	1957	79,400	55·9	100	19	119
St.-Léonard	1957	43,000	28·6	53	12	65
		122,400	84·5	153	31	184
Simplon :						
Gabi	1957	14,500	10·4	12	44	56
Zervreila :						
Seekraftwerk	1957–58	27,200	20	18·6	−3·5*	15·1
Safien–Platz	1957–58	102,000	75	110·7	38·2	148·9
Rothenbrunnen	1957–58	151,000	111	164·8	125·9	290·7
		280,200	206	294·1	160·6	454·7
Melchsee–Frutt :						
Hugschwendi	1957	19,000	13	18	19	37
Kaiserstuhl and Lungensee (additional)	1958–59	—	—	+5	—	+5
Gugra :						
Motec	1957–59	96,000	69	113	6	119
Vissoie	1957–59	64,000	45	89	92	181
Chippis, Navisence	1957–59	70,000	50	134	121	255
		230,000	164	336	219	555
Mauvoisin :						
Fionnay	1957–59	175,000	127·5	181	57	238
Riddes	1957–59	305,000	225	423	100	523
		480,000	352·5	604	157	761
Maggia (Stage 1) :						
Cavergno (Bavona)	1958	+75,000	+55	+12	+80	+92
Palasui	1958	42,000	30	31	51	82
Ritom (Unteralpreuss)	1958	—	—	12	22·5	34·5
Simmentalerwerke (Stage 1) :						
Erlenbach	1958	22,000	15·4	18·4	44·7	63·1
Mattervispwerke (Stage 1) :						
Mattsand–Ackersand II	1959	80,000	53	63	179	242
Bergeller Kraftwerke :						
Löbbia	1959–61	100,000	75	106	58	164
Castasegna	1959–61	88,000	65	131	145	276
		188,000	140	237	203	440
Blenio :						
Luzzone–Olivone–Biasca stage with Luzzone reservoir	1959–61	518,000	372	435	441	876
Göschenealp–Göschenen	1960–61	224,000	159·7	137	183	320
Consequential increases	1962	—	—	85·3	—	—
Vorderrheinwerke :						
Sedrun–Tavanasa, with Nalps reservoir (Stage 1)	1961–62	340,000	240	170	398	568

* Pumping energy.

TABLE IV—*Installed Capacity of Swiss Hydro-Electric Power Stations*

End of	MW
1930	1445
1935	1865
1940	1994
1945	2376
1950	2789
1955	3513

TABLE V—*Power Generation and Imports (millions kWh)*

Hydro-graphical year	Hydro-electric power	Thermal power	Own production	Imports	Total
1938–39	7,089	45	7,134	42	7,176
1950–51	12,191	56	12,247	406	12,653
1951–52	12,583	126	12,709	541	13,250
1952–53	13,407*	58	13,465	486	13,951*
1953–54	12,994	186	13,180	1,197	14,377
1954–55	15,381	67	15,448	625	16,073

* Including for first time Swiss share of production of Kembs station (182 million kWh in 1951–52).

As regards exports of electric energy during the hydrographical year 1954–55, amounting to 2009 million kWh, 67·5 per cent occurred during the summer (1953–54=74 per cent) and 32·5 per cent during the winter (1953–54=26 per cent). Of the imports of 625 million kWh, 85·5 per cent occurred during the winter (1953–54=77 per cent).

Inland consumption of electricity in the year 1954–55 increased by 1110 million kWh to a total of 14,064 million kWh, or 8·6 per cent. Domestic consumption showed an increase of 6·3 per cent, general industry 7·9 per cent, the chemical, metallurgical and thermal applications 12·3 per cent. Table I shows the development since 1938–39.

In the course of the five-year period 1950 to 1954 sums totalling 1490 million francs were invested in power stations, and a further 650 million francs in distribution installations. Future investments may be expected to total 500–600 million francs per annum for the next few years. Table VI shows the development of power stations above 0·3MW capacity and the likely development until 1962.

TABLE VI—*Public Supply, Railways, and Industrial Hydro-Electric Power Stations above 300 kW*

Year	Maximum installed capacity (MW)	Mean generation (millions) kWh)		
		Winter	Summer	Annual
End 1938	1,965	3,900 (44·8%)	4,810 (55·2%)	8,710 (100%)
End 1955	3,513	6,969 (45·7%)	8,281 (54·3%)	15,250 (100%)
Increase until end of 1962*	2,197	3,145† (52·7%)	2,815† (47·3%)	5,960† (100%)
Total at end of 1962	5,710	10,114† (47·8%)	11,096† (52·2%)	21,210† (100%)

* Included are only those stations which were under construction or extension in 1956.
† Including Grande Dixence (1,037 million kWh per annum, of which 561 million kWh winter power).

In these figures no allowance is made for atomic energy, an aspect to which increasing attention is being given in Switzerland, as shown by the foundation of the Reaktor A.G., Würenlingen, on March 1, 1955, in which the various electricity undertakings hold shares.

Details of hydro-electric power stations put into service in the course of last year are shown in Table II. Those under construction or undergoing alterations are listed in Table III.

Reduction of Aircraft Noise

One of the principal problems of general concern which arise from the increasing use of aircraft is the question of engine noise, particularly in view of growing use of jet propulsion. At a meeting organised by the Deutsche Arbeitsring für Lärmbekämpfung (DAL), which took place in Munich on October 15 and 16, the following aspects were discussed :—Noise levels produced by various designs of engine and the technical problems of noise reduction ; aircraft noise and health, and planning and operation of airports from the points of view of transport geography, town and country planning, and airport management.

Jumbo for bench drilling on the Ume River hydro-electric project

Rock Tunnelling on the Ume River

At a hydro-electric project on the Ume River, in North Sweden, a new record is stated to have been achieved with regard to the volume of rock removed in a tunnel operation. Work on the tunnel, which has been carried on from two headings with a height of 88ft, a width of 52ft, and a length of 2½ miles, called for the drilling, blasting and removal of some 2270 short tons of rock per month. Handling this volume in one heading has been a "Bucyrus-Eyrie 54B" 3 cubic yard excavator loading 780 cubic yards per eight-hour shift, whilst a Marion "111 M" 3·9 cubic yard excavator has loaded the 20-ton "Euclids" at the rate of 1170 cubic yards each shift.

The tunnelling method used has been top heading and benching. The top heading measured 36ft high by 52ft wide, the rest of the rock being removed in two benches, each 26ft high. Drilling equipment for the benching operation consisted of a specially designed, remote-controlled jumbo, shown in our illustration, which carried thirteen chain-fed drill hammers, covering the entire width of the tunnel. The remote control was necessitated by the possibility of the presence of undetonated explosive in the floor of the heading. After 3ft had been drilled by remote control, the ground was considered safe and the operators, each attending two drills, took over control. "Consolidated Pneumatic Fagersta Seco" 1in hexagonal drill rods were used to drill to a depth of 32ft in three changes only. The steels, each with 6½in Fagersta shanks (rubber bushings) were a starter of length 6ft 7in, the bit being a 2in integral cross bit, followed by a second rod of 19ft 9in length with a $1\frac{8}{16}$in chiselbit. The third rod, 33ft 10in in length, carried a $1^{17}/_{32}$in chislebit.

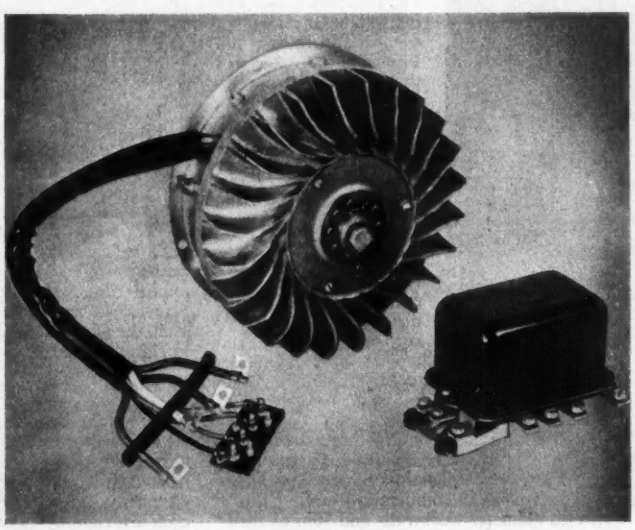
Benching holes, inclined at 2 : 1, were drilled to a depth of 32ft with a burden of 5ft 7in and were spaced 5ft 7in apart, this interval being reduced to 3ft for the holes adjoining the walls of the tunnel. In each blast, five complete rows of holes were fired together by millisecond delays, each such round using 1100 lb of explosive.

With this equipment, two crews of four miners and one mechanic drilled five rows of holes in each heading per shift. On a twenty-day month, this amounted to a total tunnel advance of 1120ft.

Lightweight Pendulum Starter Dynamo

In our accompanying illustration we show a lightweight combination equipment developed by Robert Bosch G.m.b.H., Stuttgart, German Federal Republic. The equipment combines in one machine a dynamo, starter motor, and ignition contact breaker. It has been specially designed for single-cylinder, two-stroke engines, as used in motor scooters and light cars, and enables such vehicles to be started and operated by means of a comparatively small 6V battery.

The principle of the pendulum starter consists of imparting an oscillating rotation to the crankshaft, on which it is directly mounted. In this way it does not have to overcome the full compression at each revolution, but gradually builds up kinetic energy, at the same time charging the cylinder. By means of a "starting ignition" the engine is then accelerated in the correct sense of rotation and continues to run with normally operating ignition.



Lightweight pendulum starter-dynamo for two-stroke single-cylinder engines. On the right is the regulator

The moving parts which, as has been mentioned, are directly coupled to the crankshaft, comprise the wound rotor, the commutator, cams for the pendulum action and the ignition circuit breaker, and, if required, a fan for cooling the engine.

Fixed parts, arranged for mounting on the crankcase, are the eight-pole stator housing, with one shunt winding each for starting and for generating current. At the end of the stator housing are attached the holders for the two carbon bushes, the circuit breakers for oscillatory motion and for ignition, a lubricating felt for the cams, and the condenser for spark suppression at the contact breakers.

A regulator switch for controlling the starting process, and also the dynamo voltage and for switching the battery on and off, is housed separately and may be seen on the right in our illustration. In addition, there are the necessary manual switches—which are not illustrated—for light, ignition and starting, as well as the separately mounted ignition coil. Holes in the fan permit the ignition to be adjusted with the fan in position. These holes are normally covered by a metal disc.

The dynamo, which is designed for operation between 1700 and 5500 r.p.m. (short bursts of speed in excess of this figure being permissible), has a nominal output of 60W and is arranged to withstand up to 50 per cent continuous overload, i.e. a maximum current of 15A. The starter has a maximum power of about 0·15 h.p. at 20 deg. Cent. and with the battery half-charged; mean starting current is 40A to 50A.

The moment of inertia of the rotating parts is 377 kg centimetre squared (including fan). Total weight is 7·8 kg and a 11–18Ah battery is required. Similar equipment is also made for 12V, giving up to about 0·3 h.p. during starting. The agent in the U.K. is Bosch, Ltd., 20, Carlisle Road, The Hyde, London, N.W.9.

Annual Report of A.I.B

The sixty-sixth annual report has now been published of the Association des Industries de Belgique (A.I.B.), the Belgian Society for the Prevention of Industrial Accidents. The Society counts among its governing body members from all branches of Belgian industry, and has a staff of fifteen diplomate engineers, twenty-two engineer technicians, and 242 inspectors and other employees. It is organised in twenty-seven divisions, which range from security and accident prevention itself to hygiene, laboratory and testing services, and documentation; there is included a special division which deals with technical surveillance in the Congo dependencies of the Gouvernement Général and of Ruanda-Urundi.

In his report to the annual general meeting on March 22, 1956, the president, Monsieur Jacques Henricot, gave details of the varied activities of the Society. He referred to the International Conference on non-destructive testing, held in May of last year, and also mentioned the conference on the adaptation of the machine to the operator. A new maximum of 10,519 members was reached last year (9469 in 1954).

Radioactivity Measurements in Germany

According to the chairman of German Committee on Radioactivity, Professor Rajewski, a network of observatories for radioactivity is to be established in the Federal Republic. The work will be spread over two years and will, it is estimated, cost between 500,000 and 1,000,000 DM. In order to maintain its independence the new organisation is to receive its grant directly from parliament and not through a ministry.

The first task will be to meaure the natural background of radiation in each locality, which will serve as a basis against which future variations can be assessed. A central office is to be given the task of evaluating the results of measurements and the effects which the detected radiation is likely to have on animals, plants and humans. Measurements so far obtained are to be published in the near future.

Fabrication of Fuel Elements for Nuclear Reactors

BY OUR AMERICAN EDITOR

No. II—(*Concluded from page 753, November 23*)

The growing interest in the commercial applications of atomic energy has led to more than twenty American firms entering the field of producing fuel elements and related reactor components. This development is encouraged by the U.S. Atomic Energy Commission, which now purchases its fuel element requirements from private industry. In line with the majority of current reactor designs, most of the fuel elements now being manufactured are of the flat plate form. This article primarily deals with flat elements and reviews the special fabrication methods required in their production.

Glovebox Enclosures

FIG. 9 shows an interesting two-high/four-high combination rolling mill equipped with a special remote control roll removal mechanism and arranged to operate within a glovebox enclosure. This unit was developed originally for the processing of alpha-active, pyrophoric materials at the Argonne Plutonium Metallurgy Research Laboratory and has subsequently also been installed at the Hanford Works of General Electric. The design of the latest Argonne gloveboxes is based generally on a 36in long module and an inter-glove spacing of 18in. The glovebox windows are made of clear, transparent, cast "CR-39" allyl polymer material, which is made by the Cast Optics Corporation, of Hackensack, New Jersey, and has a high degree of resistance to scratching, impact, stress crazing and chemical attack. The gloves are made of "neoprene," and polyvinylchloride transfer pouches are used to contain the plutonium pieces handled. The glovebox must be essentially gastight, both to protect against contamination leakage and to maintain the desired inert gas atmosphere economically. In accordance with current practice at Argonne, a helium circulating system is employed within the gloveboxes, the internal gas pressure being controlled between −0·5in and −1·5in of water. It is very important to obtain a satisfactory seal on shafts passing through the glovebox walls, such as the extended pinion shafts and the screwdown adjustment shafts in the case of the mill shown in Fig. 9.

Fig. 9—Combination rolling mill with roll removal slide prior to installation within a glovebox at the Argonne National Laboratory

Standard O-ring gaskets have been found to make satisfactory seals and are now in general use for glovebox applications. In accordance with normal vacuum technique, rotating shafts are carried through the glovebox wall by means of a substantial metallic flange which is O-ring-gasketed to the wall. In turn, the shaft itself is passed through a commercially available cartridge seal mounted on the flange. From a structural point of view the glovebox containing the rolling mill comprises corner members extruded from 61S-T6 aluminium alloy, which shows good hardness and wear resistance. Fig. 10 illustrates a representative longitudinal corner member used to clamp the glovebox structure to the machined ¾in thick flange of the rolling mill baseplate.

In view of the Argonne National Laboratory's interest in fast breeder reactor power stations, its metallurgy division is particularly concerned with the processing of plutonium and its alloys. Plutonium fuel elements have already been used in the Argonne Experimental Breeder Reactor No. 1 and are providing important technical data on breeding and control behaviour. The Experimental Breeder Reactor No. 2, which will be considerably more powerful with a heat output of 62·5MW is now being developed by Argonne, and is scheduled to become critical at Arco Idaho, in 1958. A facility for the development and the experimental fabrication of fuel elements containing plutonium is an essential requirement for the development of such fast breeder reactor power plants, and such a facility, comprising large-scale gloveboxes, is now under construction at Argonne. The basic layout of this workshop is in the form of a herringbone, with a central, enclosed conveyor system and integral branches eliminating the air transfer of materials between operations. The various processes arranged in herringbone formation, alternately on the two sides of the central 102ft conveyor, are as follows : machine shop, aqueous solution, pressing and powder metallurgy, weighing and inspection, wire fabrication, centrifugal casting, plate shear, ingot casting, and rolling mill. Provision is made for three additional lines to be added to this scheme, if required. Gastight valves separate the branch gloveboxes from the central conveyor. Every item entering the main glovebox system is assumed immediately to be contaminated beyond tolerance. Auxiliary equipment outside the primary gloveboxes, such as vacuum and hydraulic systems, mechanical drive assemblies and seals, which may be contaminated by gasket or joint failure, are also housed in protective hood enclosures.

In Fig. 11 we show one of the two principal rolling mills which are being installed in the above plant. Both these mills are "Stanat" reversible two-high/four-high combination rolling mills with 2½in diameter work rolls and 10in diameter backup rolls. Each mill is driven by a 50 h.p. d.c. motor through an "extra-heavy-duty" combination speed reducer and pinion stand and has a 40ft. to 160ft per minute constant horsepower range. A constant torque speed range from 5ft to 40ft per minute is also available. The mill has "Orange" cage type needle roller bearings on the roll necks and possesses a maximum separating force capacity of 600,000 lb at a rolling speed of 100ft per minute. The power screwdown system of the mill comprises a 2 h.p. variable-speed drive geared to give screwdown speeds of 0·15in to 0·60in per minute.

Since the entire mill up to the pinion stand is enclosed in a glovebox system, special provisions had to be made to facilitate the feeding of workpieces and changing of rolls. Fig. 11 shows also the power-operated roll change mechanism, which allows the entire roll assembly—either two-high or four-high—to be withdrawn from the mill housings. Once this has been accomplished an overhead crane is available within the glovebox enclosure to change the roll assemblies as well as the individual rolls. The universal joint spindles of the mill are equipped with the special support cradle, shown in Fig. 12, to maintain their position while the roll assemblies are withdrawn from the mill. The machine is provided with plain rolls for flat rolling and grooved rolls for the production of shapes.

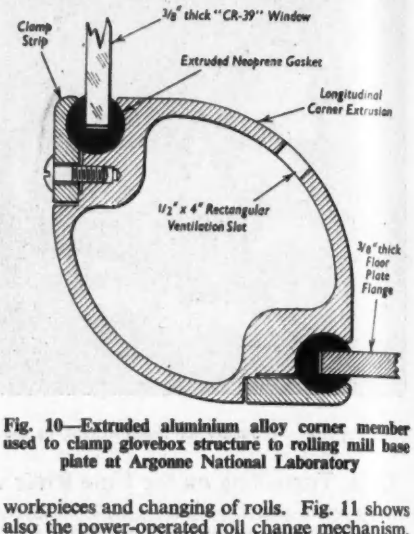


Fig. 10—Extruded aluminium alloy corner member used to clamp glovebox structure to rolling mill base plate at Argonne National Laboratory

Slitting and Levelling

In addition to rolling mills, two other important items of metal processing machinery, often required for the production of fuel elements and other reactor components, are rotary gang slitters and roller levellers. Slitters are needed primarily for edge trimming purposes and are required to hold width tolerances as close as plus or minus 0·001in. In Fig. 13 we show a 12in wide slitter installed at the Oak Ridge works of the Union Carbide Nuclear Company. The machine has 2½in diameter arbors and uses 5½in diameter cutters. It is driven by a 3 h.p. motor and can handle sheet thicknesses up to $^{9}/_{32}$in.

Another machine installed at Oak Ridge is the roller leveller illustrated in Fig. 14. This unit is intended particularly to handle aluminium and stainless steel clad fuel elements in a 0·020in to 0·125in thickness range and in widths up to 12in. The machine has nine levelling rolls, each 2in diameter by 12½in wide, and two exit pinch rolls, each 3in diameter by 12½in wide. All rolls are positively driven through heat-treated alloy steel helical gearing and run in needle roller bearings. The leveller has a 3 h.p., 40ft per minute drive, with forward and reverse control. Screwdown adjustment is provided at the front and rear of the machine to control the degree of levelling applied to the fuel element sheets.

Sequence of Fabrication

The design of a representative plate type fuel element is illustrated in Fig. 15. It was originally developed for the Consolidated Edison reactor now being built by the Babcock and Wilcox Company. The Consolidated Edison reactor core is a right cylinder about 6ft high and about 6ft in mean diameter. It is made up of more than 100 fuel elements like that shown in Fig. 15, containing alternate fuel and fertile or breeder

plates separated by coolant channels. The fuel plates are 0·060in thick and are made up of highly enriched uranium-Zircaloy-2 "meat" clad with Zircaloy-2. (Note: the nominal composition of the Zircaloy-2 alloy is: 1·50 per cent tin, 0·12 per cent iron, 0·05 per cent nickel, 0·10 per cent chromium and balance zirconium.) The fertile plates are 0·080in thick and consist of thorium "meat" clad with Zircaloy-2. The coolant channels are 0·100in wide.

The sequence of operations required to fabricate these fuel elements was described in our article entitled "Industrial Nuclear Facilities Works in Virginia," No. II, page 176, August 3, 1956.

Reprocessing of Spent Fuel

As the construction of nuclear power plants is proceeding, serious thought has to be given to the removal of depleted fuel elements from the reactor vessel, the cooling to reduce radioactivity, the reprocessing of the spent fuel, the disposal of radioactive wastes and the reintroduction of the newly assembled fuel elements in the reactor. Unfortunately, nuclear reactors, unlike conventional boilers, do not "burn" all of the fuel inserted into them. Only a small part of each charge is consumed before the reactor must be reloaded, either because of radiation damage to the fuel element, accumulation of nuclear poisons, or because of the lack of enough fissionable material to maintain the chain reaction.

Spent fuel reprocessing involves extreme hazards due to the high levels of radiation involved. Accordingly, the major portion of such operations must be done within a shielded "cave" by remote control. This, in turn, calls for specially designed melting, casting, fabrication and assembly equipment all capable of functioning under the "hot" conditions prevailing within this area.

Fuel elements may be reprocessed by either the application of aqueous chemistry or of metallurgical methods. The Argonne National Laboratory recently developed a pyrometallurgical method of reprocessing known as "oxidative slagging." In this process, certain fission products are selectively converted to oxides and are accumulated in a slag layer. The method is designed to remove from irradiated uranium or uranium-plutonium alloys a significant part of the fission product elements, thus permitting the re-use of the metal as nuclear reactor fuel. After oxidative slagging, the metal is put through the usual cycle of ingot casting to fuel element assembly, except that all necessary operations are performed by remote control within a shielded area. A remotely operated fuel element reprocessing facility of this kind is being developed for the Detroit Fast Breeder Power Reactor by Atomic Power Development Associates, Incorporated. This shows an interest being taken by private enterprise in this field and indicates a future trend, when the A.E.C. will cease to be the only American source of reprocessing irradiated fuel elements.

Early this year, the A.E.C. approved a programme to encourage private industry to build and operate plants for the chemical processing of irradiated fuel elements from research and power reactors. The Commission recognised that a truly competitive nuclear power industry, free from major dependence on Government assistance, will not come into being until all facets of the nuclear reactor cycle—including power reactor operation, fuel element fabrication, feed materials preparation, fuel processing and fission product recovery—are being carried on by industry in privately owned facilities. It also recognised that the costs of each of these segments of the reactor cycle must be brought down to levels permitting the economic production of nuclear power. The programme which the A.E.C. has developed for encouraging the industrial processing of irradiated fuels from privately owned reactors is briefly as follows:—

(1) All available A.E.C. technology on chemical processing will be made available to industry, through appropriate means such as reports, seminars, and works visits in accordance

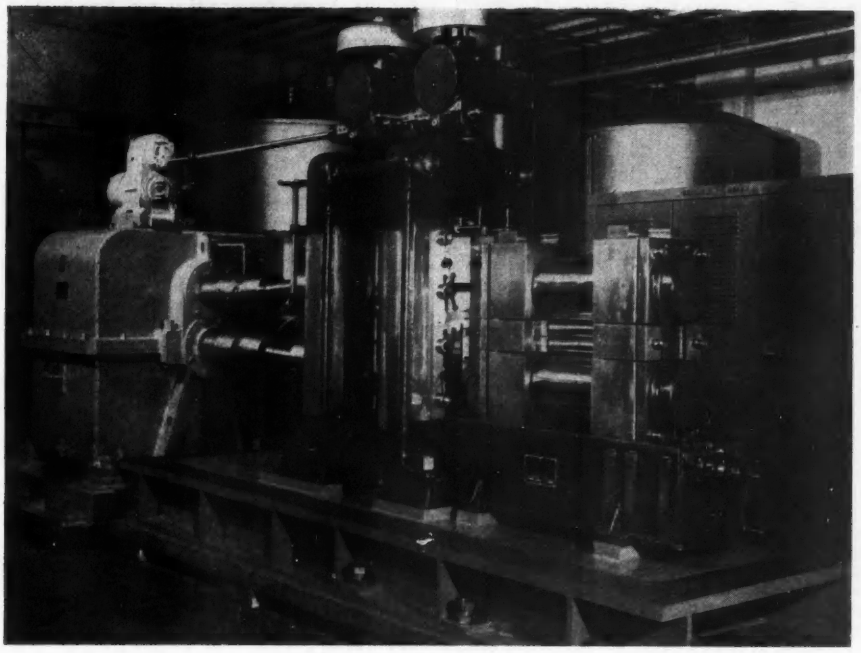
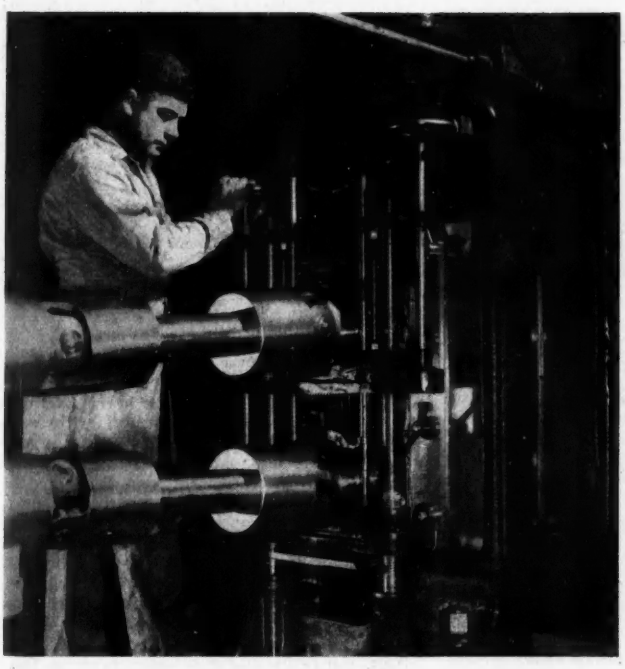
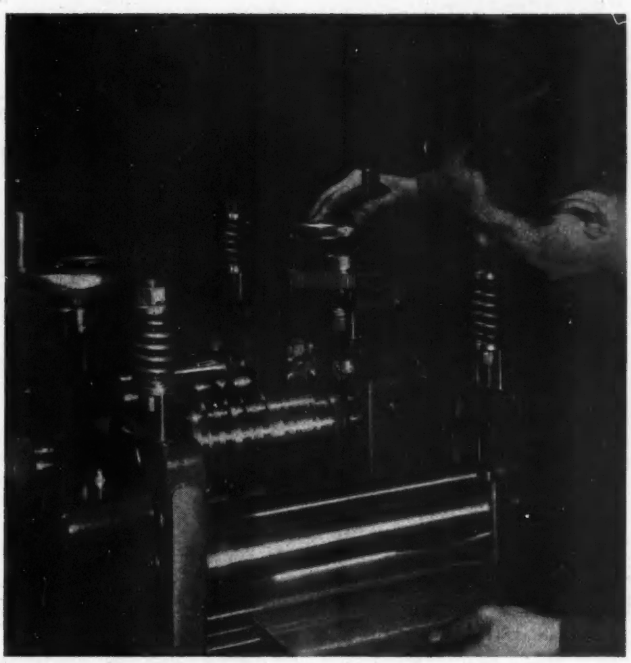


Fig. 11—2½in and 10in by 14in, two-high/four-high combination rolling mill with 50 h.p. d.c. drive installed at the Argonne National Laboratory





Figs. 12 and 13—(Left) Combination rolling mill support cradle to maintain universal joint spindle position during the withdrawal of roll assemblies from the machine. (Right) 12in wide rotary gang slitter with 2½in arbors and 5½in cutters employed to shear fuel element sheets

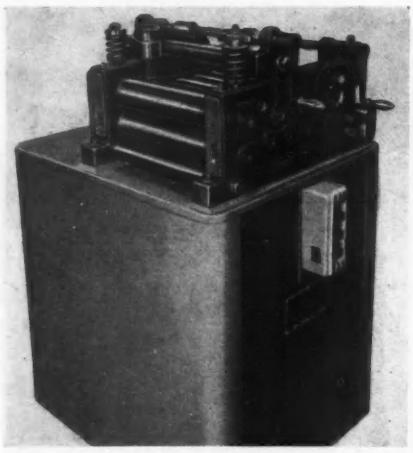


Fig. 14—12in wide roller leveller with nine 2in diameter levelling rolls employed to straighten fuel elements sheets

with regulations governing the access permit programme.

(2) A description of the kinds and amounts of miscellaneous irradiated fuels expected to be available in the foreseeable future from certain A.E.C. reactors, from military reactors, from privately owned research reactors and from foreign sources, will be made available.

(3) The Metal Recovery Plant at Oak Ridge and the Idaho Chemical Processing Plant were built primarily for developmental purposes and for the recovery of source and special nuclear materials from Government reactor fuels, and the A.E.C. would prefer not to employ them as service facilities for processing fuels from the atomic power industry.

(4) The A.E.C. will consider making available to industry for set periods of time certain fuels for processing. Included in such fuels would be materials from A.E.C. reactors, university, institutional and industrial research reactors, and from foreign reactors.

(5) The A.E.C. will permit the use of its facilities to the extent that they can be made available to industry for development work and other related purposes, with the full cost of such use to be recovered by the A.E.C. Patent provisions to cover the use of such A.E.C.-owned facilities would be incorporated in such an arrangement.

(6) The A.E.C. will invite proposals from industry to be submitted at an appropriate time, for the design, construction and operation of chemical processing plants, capable of processing one or more of the fuels, which will be employed in the projected industrial power reactors, together with limited quantities of irradiated materials from A.E.C. reactors. Industry would be advised to include in these proposals a description of their plans for research and development facilities. It is estimated that such proposals would be called for submission some time in 1957. This allows a reasonable time for all interested parties to become acquainted with the processes involved in existing plants, and to do preliminary development and design work.

The importance of the reactor fuel reprocessing problem was well summed up recently by W. K. Davis, Director of the Division of Reactor Development of the A.E.C., when addressing a Power Reactor Fuel Processing Symposium in Idaho: "In closing I would like to state that the chemical processing of irradiated fuel from private power reactors is a tremendous challenge for industry and one that can best be met by industry. There is a stake not only in the economic production of nuclear power, but also the recovery of the fission products in the spent fuel. For processors a major incentive lies in the recovery of these fission products for commercial utilisation purposes. What is now a costly waste problem to the A.E.C. may be an untapped source of profit to industry. The potentials of sterilising food, promotion of chemical reactions, packaged power sources, medical and industrial tools are also in Pandora's box: we have tried many keys, but there are many, many more compartments to be explored."

Recovery of Uranium Scrap

While at present there are more than twenty American firms engaged in the manufacture of reactor fuel elements, all scrap reclamation work in connection with these operations is still in the hands of the A.E.C. With the requirements for nuclear fuel for commercial reactors increasing at a rapid rate, it is now felt in America that it would be unwise to depend upon a governmental operation for the total scrap recovery requirement.

The scrap which issues from a representative fabrication works consists largely of fuel element rejects. However, one must also consider dross, choppings, pickling tank sludge, abraded material, degraded particles of oxide, and even floor sweepings and filter dust from material valuable enough to warrant such recovery. Some of the scrap can be re-used by recycling it directly a step or two ahead in the fabrication plant. Other material must be subjected to more elaborate treatment. The following table No. I shows in a general way some typical scrap materials and the probable treatment which they require.

The metallic alloys appearing as the first three entries in the table can be remelted in some cases and re-alloyed with additional feed.

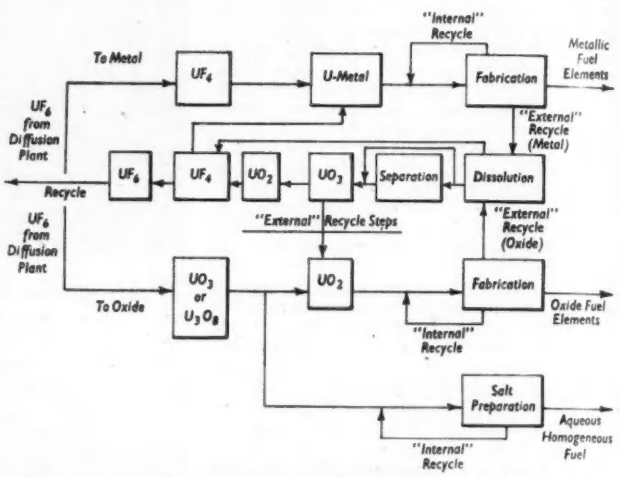


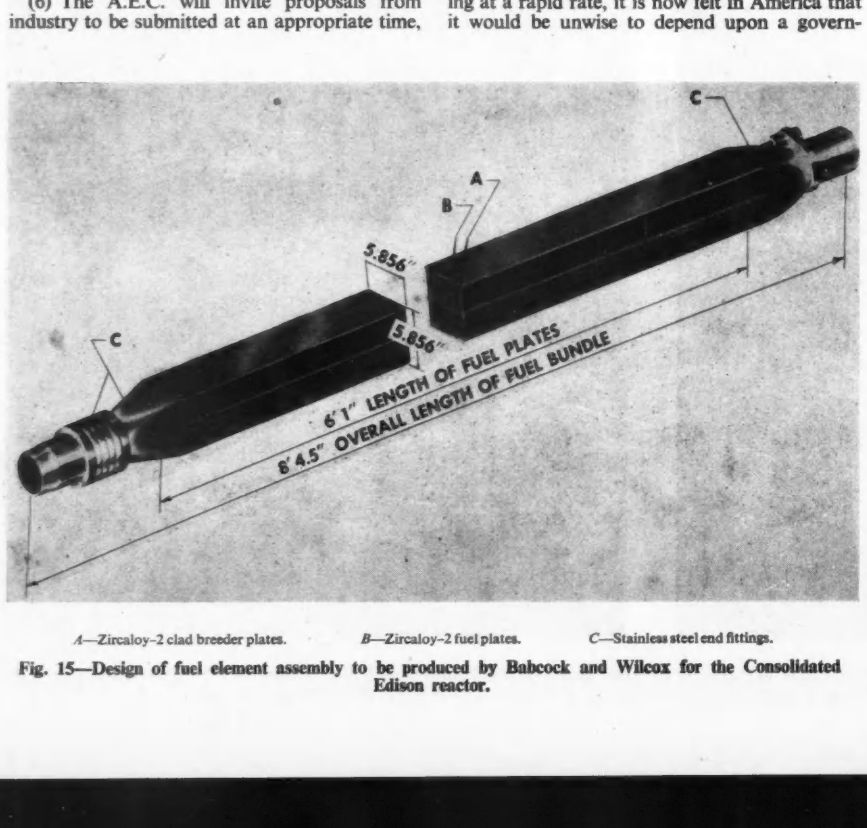
Fig. 16—Schematic flow diagram showing the major steps involved in the manufacture of fuel and fertile elements

If this is not possible, the rejects must be dissolved in a suitable acid, after which the uranium must be separated from the alloy material, and then recovered in a form capable of re-use. In some fuel elements using uranium dioxide all rejects must be recycled externally, i.e. by dissolution and recovery, by the time the fuel element is completed and tested. Some internal recycling of oxide is possible in other methods of producing this kind of element. The treatment of dross, analytical solutions and other miscellaneous scrap almost always involves chemical steps and therefore will generally involve "external" processing.

Table I—*Types of Scrap and Treatment*

Type	Probable treatment
(1) U–Al alloy scrap	Remelt stock for alloying; chemical dissolution (nitric acid) and recovery
(2) U–Zr alloy scrap	Remelt stock for alloying; chemical dissolution (hydrofluoric acid); separation of U–Zr and recovery
(3) U alloyed with Nb, Mo, V, Ni, &c.	Possible remelt stock; chemical dissolution; separation and recovery
(4) UO_2–stainless steel ...	Chemical dissolution (nitric acid); separation and recovery; possible direct re-use of UO_2
(5) UO_2—alone or with admixed metals	Chemical dissolution; separation and recovery
(6) Dross from melting crucibles and abraded U-alloy residue	Chemical dissolution; separation and recovery
(7) Analytical residues of U and associated metals	Chemical recovery as U-salts
(8) Miscellaneous residues, such as iron "picture frames," floor sweepings, filters, ashes, sludges from etching and pickling operations, &c.	Chemical dissolution and/or recovery as U-salts or discard to waste

The materials considered in Table I above are associated mainly with solid fuel elements. The manufacture of aqueous homogeneous fuel solutions will probably involve only a small amount of "scrap" for recycling, and most of this will be carried out as an integral portion of the manufacture. With regard to liquid metal fuels, the main source of scrap is dross from melting crucibles which must be recycled by "external" chemical dissolution and recovery,



A—Zircaloy-2 clad breeder plates. *B*—Zircaloy-2 fuel plates. *C*—Stainless steel end fittings.

Fig. 15—Design of fuel element assembly to be produced by Babcock and Wilcox for the Consolidated Edison reactor.

as shown in the table. Liquid fuels are not expected to contribute much to the total quantity of scrap, at least in the early stages of nuclear power.

Table II lists the various kinds of scrap

TABLE II—*Typical Breakdown of Uranium-Aluminium Alloy Fuel Fabrication*

	Per cent
Finished product	60
Re-usable scrap (most, probably "internal" to fabrication plant)	30
Recoverable scrap (most, probably "external" to fabrication plant)	5
"Non-recoverable" scrap (recovery depends on marginal economics)	4
Unaccounted and known losses	1
Total, input	100

which might be experienced in the manufacture of uranium-aluminium alloy fuel elements. From this table it can be seen that, on the basis of long and short production runs of fuel elements of different shapes and compositions an average yield of only 60 per cent is expected. Yield is here considered to be the number of kilogrammes of uranium leaving the plant as finished product without recycling compared to the number of kilogrammes brought into the plant. There would be a large degree of internal recycling which indicates that most rejects can be remelted and re-alloyed directly. Fuel fabrication involving uranium, alloyed or clad with stainless steel, zirconium, molybdenum, vanadium, nickel, &c., will probably have a somewhat lower net yield, a lower re-usable internal scrap and a higher recoverable external scrap, at least in the early stages of manufacture, than the comparable quantities for uranium-aluminium alloy.

The scrap resulting from oxide fuel manufacture is also expected to vary considerably from the figures for uranium-aluminium. If the element has been completed and found defective, depending upon the method of manufacture, it may be very difficult to reclaim the UO_2, as such, for internal recycling. Recycling of some UO_2, for various reasons, is often necessary prior to the cladding step. The recoverable scrap may be considerably higher than for uranium-aluminium, depending, however, on the method of manufacture. The method of recovery in this case also depends very much on the method of fabrication.

At this stage, it is difficult to predict what improvements will come about in fuel fabrication techniques to reduce external scrap. For the power reactors at present conceived, it is likely that the external scrap will vary between about 15 and 25 per cent of initial feed to the fabrication plant for uranium-zirconium and uranium-stainless steel alloys and very probably for UO_2 elements; these are at present the most popular solid fuel elements. Where definite data on scrap percentages are lacking, it would seem appropriate to use a nominal value of about 20 per cent external recycling. The use of this figure, 20 per cent, in studying the economics of scrap from the point of view of the current American reactor programme is probably valid even though it may not be correct. Even though the percentage of scrap to usable product is expected to decrease, the demand upon fabrication works for nuclear fuel will probably increase at a rate that will at least ensure a steady growth in the total annual quantities of scrap which must be reclaimed.

Fig. 16 is a schematic flow diagram of the important steps involved in the manufacture of finished fuel or fertile elements, starting with UF_6 from the gaseous diffusion plant. The upper stream indicates representative steps required to prepare metallic elements, while the lower stream shows representative steps involved in the preparation of oxide elements, or uranium salts for homogeneous fuel. In the middle are shown representative operations required in recycling scrap material either back to the fabrication plant or back to the diffusion plant as UF_6. As shown on the diagram, some internal recycling is possible. From the scrap reclamation point of view, the interest, however, is in the external steps required to complete the cycle. Although both oxide and metallic fuels are shown as being recycled through the same stream, it is not necessarily true that the same equipment can be used for both.

The steps for the recovery of solid scrap material involve such processes as dissolution in acids; separation from alloy materials; conversion to UO_3 by evaporation and denitration; and reduction to UO_2 with hydrogen and hydrofluorination to UF_4. The resulting UF_4 can be recycled directly to the metal step of metallic-element manufacture, or the UO_2 returned to the UO_2 step of the oxide-element stream. When UF_4 results from the dissolution step, it may be possible to return the UF_4 directly to the metal step of the metallic-element process. Although the recycling steps from separation to the UF_4 and UF_6 are the same as those involved in preparing normal UF_6 (or metal), the industrial scrap reclamation process will probably involve the use of much smaller equipment than that involved in the large-scale uranium treatment plant of the A.E.C. In addition, while the feed preparation is continuous at works of the A.E.C., the scrap recycling would have to be either on a batch or intermittent-continuous basis to allow different enrichments to be handled in the same equipment with the minimum of mixing. Furthermore, the scrap-recovery equipment can be highly flexible to allow any special treatment of scrap which is required. Thus, critical mass considerations often dictate the size of equipment in which uranium is processed.

Since the equipment is expected to be small, scrap recovery appears to offer opportunities to those smaller industrial concerns who are seeking a place in the atomic energy picture. In many cases the value of the scrap warrants the potentially more expensive treatment implied by small-scale, flexible, batch equipment. A further opportunity is apparent when one realises that some of the steps in the external scrap recovery are similar or identical to steps in the direct manufacture of metal or oxide. Thus, a works handling the direct manufacture of nuclear fuels might also, with only slight modification or addition, be able to treat the recycling scrap. Another interesting possibility is apparent from the diagram. The dissolution and separation steps are in many respects similar to some of the steps involved in the recovery of uranium from irradiated fuel elements. Since the scrap under consideration here is non-radioactive, it appears that it might serve as a "pay-load" for pilot plants concerned with the recovery from irradiated fuel. Many of the unknowns in the operation of an irradiated-fuel process could be investigated in an unshielded, directly-maintained plant, handling the scrap from the fabrication of the same fuel that would ultimately be returned in the irradiated condition. All of this information could be directly applied to the final process to be used for the irradiated fuel, and a profit might be realised while obtaining it.

It is of interest to note that in order to stimulate public interest in the industrial participation in uranium-scrap recovery, the U.S. Atomic Energy Commission held a classified technical meeting last month at Oak Ridge, Tennessee, open to American "access permit" holders. This meeting was devoted generally to the processing of unirradiated enriched uranium and, it is hoped, will result in several industrial concerns setting up a commercial scrap recovery service.

Award of the A.S.M.E. Medal

THE American Society of Mechanical Engineers recently announced that Mr. Harry F. Vickers, the president of the Sperry Rand Corporation, will receive this year's A.S.M.E. Medal, for "distinguished service in engineering and science." Mr. Vickers, who has been the president of Sperry Rand since its formation in 1955 with the consolidation of the Sperry Corporation and Remington Rand, Incorporated, has a long record of engineering achievement and industrial administration. He will be cited in particular for "pioneering in industrial oil hydraulics and for notable accomplishments in business leadership." He holds ninety-five patents covering hydraulic and other devices. The A.S.M.E. Medal is the Society's second-highest honour, and is surpassed only by the award of honorary membership. It has been given annually since 1920 to such leaders as Charles F. Kettering, of the General Motors Corporation; Edward G. Budd, the developer of stainless steel railway coaches, and the late Dr. Robert A. Millikan, the Nobel Prize winner, for research in the field of physics.

Much of Mr. Vickers' work has been concerned with naval ordnance. His work during the 1930s led to completely new systems of hydraulically operated ammunition handling and naval gun operation. Mr. Vickers started his own business to build hydraulic equipment in Los Angeles in 1921, after interrupting his education to serve with the U.S. Army Signal Corps in France during World War I. The company, Vickers, Incorporated, moved to Detroit in 1930, where it became the largest of its kind in the United States and eventually merged with the Sperry Corporation.

Nuclear Propulsion Plant for Merchant Vessel

THE U.S. Atomic Energy Commission has accepted as a basis for contract negotiations a proposal by the Babcock and Wilcox Company, of New York, to design, build and test operate a nuclear propulsion plant for a nuclear-powered merchant ship. The award of a contract will depend on the successful completion of the authorised negotiations. The ship itself will be built under contract to the Maritime Administration of the U.S. Department of Commerce. Under the proposed contract Babcock and Wilcox will design, build and test operate a 20,000 s.h.p. pressurised water reactor system of advanced design. The project is to be completed in thirty-nine months.

The pressurised water reactor system was chosen to power the merchant ship because a large background of fundamental information has been accumulated in experience to date on this design. Consequently, it offers the best prospect for achieving desired technological advances in a relatively short time. The selection of this concept of demonstrated operability will also ensure that there will be an early opportunity to study the practical aspects of operating nuclear-powered merchant vessels. The reactor for this first nuclear-powered ship will be unclassified and the new technology developed in this project will be available to American industry.

A.E.C. Fellowships in Nuclear Energy Technology

THE U.S. Atomic Energy Commission has established a programme of special fellowships to encourage more students to pursue courses of study in the physical sciences and nuclear engineering. The fellowships are part of the Commission's general programme of assistance in the field of education for the purpose of alleviating the shortage of trained nuclear scientists and engineers. The programme will be administered by the Oak Ridge Institute of Nuclear Studies, under the supervision of the Oak Ridge Operations Office of the Commission. The Institute now administers for the Commission the Special Fellowships in Radiological Physics, the Special Fellowships in Industrial Hygiene, and the post-graduate fellowship programme.

About 150 fellowships carrying stipends of 1800 dollars, together with tuition and dependency allowances, will be awarded to students registered in, or accepted by, a college or university where a programme of graduate study in nuclear energy technology has been developed which is comparable to the one-year course of study at the Commission schools. Because of the time required to review applications and select fellows, it is expected that only a limited number of fellowships will be awarded for studies in the current academic year. Fellowships will be awarded on a one-year study basis and options to renew them for one additional year will be considered only under special circumstances. The final selection of candidates will be made by a committee of representatives of Oak Ridge and the Commission.

Personal and Business

Appointments

DR. W. H. GARRETT has been appointed an additional director of Metal Industries, Ltd.

MR. T. A. EMERSON has been appointed divisional sales manager of Millars' Machinery Company, Ltd.

LORD SEMPILL has been elected president of the Institution of Engineers-in-Charge for the session 1956–57.

F. PERKINS, Ltd., Peterborough, announces the appointment of Mr. Geoffrey Jones as manager of the inspection department.

MR. TONY LACEY has been appointed to the publicity department of The Fairey Aviation Company, Ltd., 24, Bruton Street, London, W.1.

MR. K. D. RUTTER has been appointed sales manager of Gemec Chemicals Company (a division of Union Carbide, Ltd.), 120, Moorgate, London, E.C.2.

MR. E. A. HUNT has been appointed production controller, and Mr. T. D. Lund, senior production engineer, of The Hymatic Engineering Company, Ltd., Redditch, Worcs.

MR. W. S. BOONE, publicity manager of Johnson and Phillips, Ltd., and Mr. J. Read, publicity manager of Standard Telephones and Cables, Ltd., have been appointed to the BEAMA publicity committee.

THE POWER-GAS CORPORATION, Ltd., Stockton-on-Tees, states that Mr. P. M. K. Embling and Mr. D. R. Brown have been appointed divisional directors. Mr. Embling is responsible for the chemical plant division and Mr. Brown for the blast-furnace division.

FERODO, Ltd., Chapel-en-le-Frith, Stockport, announces the following appointments:—Mr. K. A. Appleton, manager of the Liverpool depot; Mr. A. H. Collinson, manager of sales (replacements) department; Mr. R. S. Henson, competitions manager.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, has announced the following appointments: Mr. F. R. Harris, A.M.I.Mech.E., assistant chief engineer, gas turbine engineering department; Mr. G. H. Moule, assistant chief engineer (heating), heating and welding department.

THE MINISTRY OF SUPPLY states that Mr. J. F. Shearer has been appointed to the Royal Ordnance Board. He succeeds Mr. H. A. Benson, who is retiring from the Board at the end of the year, owing to pressure of other work. Other appointments announced this week by the Ministry of Supply are: Dr. A. W. Lines, senior superintendent, research and assessment division of the guided weapons department at the Royal Aircraft Establishment, Farnborough; Mr. W. J. Brown, director of weapons production; Mr. C. S. Tafft, director of fighting vehicles production.

Business Announcements

MR. J. W. WHIMPENNY, joint managing director of W. H. Dorman and Co., Ltd., is making a tour of South America.

SQUARE D, Ltd., has opened a northern area office at 4, Minshull Street, Manchester, 1 (telephone, Central 9757).

GIBBONS BROTHERS, Ltd., Dudley, has acquired an interest in Metallurgical Oxygen Processes, Ltd., Granite House, Cannon Street, London, E.C.4.

CONNOLLYS (BLACKLEY), Ltd., has opened a new sales office for the Midlands at 39-44, Watery Lane, Bordesley, Birmingham, 9 (telephone, Victoria 4991).

THE NATIONAL COAL BOARD states that Major-General Sir Noel Holmes is to retire from the chairmanship of the North Eastern Division on January 31, 1957.

VULCAN PRODUCTS, Ltd., Slough, states that it has ceased production of decorating paints except for factory maintenance work. Its activities are now concentrated on industrial and transport finishes.

THE KOEHRING COMPANY, Milwaukee, and the Buffalo-Springfield Roller Company, Springfield, Ohio, have announced plans for a merger which will take effect on December 1.

INTERNATIONAL COMBUSTION, Ltd., states thatMr. J. C. Farrant has now retired. For some years he was manager of the grinding, screening and filtering division, and has latterly acted as an advisor to the organisation.

THE HYMATIC ENGINEERING COMPANY, Ltd., of Redditch, Worcs, has built a new factory for its automation division, which is equipped exclusively for the design, development and manufacture of automatic linking devices.

THE GENERAL ELECTRIC COMPANY, Ltd., and the BRITISH TABULATING MACHINE COMPANY, Ltd., have now announced further details of the company which they have formed jointly to further their collaboration in the design of computers and similar equipment. The company is entitled Computer Developments, Ltd. The chairman is Mr. H. V. Stammers, representing the British Tabulating Machine Company, Ltd., and the deputy chairman is Mr. T. W. Heather, of The General Electric Company, Ltd. Dr. D. C. Espley, of the G.E.C., has been appointed chief executive of the new company, which will operate, from January next, at Computer House, 390-394, Kenton Road, Kenton, Middlesex.

Contracts

THE Canadian subsidiary of Tangyes, Ltd., Smethwick, has acquired a contract valued at 150,000 Canadian dollars for hydraulic equipment to be used in raising the Jacques Cartier bridge. This project was described in THE ENGINEER of November 9th last.

BRUSH ELECTRICAL ENGINEERING COMPANY, Ltd., has obtained through Kellogg International, an order for six gas expansion turbines to be installed in a new chemical plant by Imperial Chemical Industries, Ltd., Billingham Division. These turbines will range in output from 3000 h.p. downwards, and will be used for driving centrifugal compressors. The gas for driving the turbines will come from an installation of fifteen GS34 free-piston gasifiers, which will be supplied partly by S.I.G.M.A. in France, and partly by the Free Piston Engine Company, Ltd.

SIMON-CARVES, Ltd., has received an order from the Steel Company of Wales, Ltd., to supply the first Benson "once through" forced-circulation boiler to be ordered in Great Britain. It will be installed in an extension of Margam "B" power station and will be designed to generate 240,000 lb of steam per hour at 3300 lb per square inch and 1060 deg. Fah., with reheat to 840 deg. Fah.—the most advanced steam conditions yet to be used commercially in this country.

RICHARDSONS WESTGARTH (HARTLEPOOL), Ltd., has received an order from the Steel Company of Wales, Ltd., for a high-pressure steam turbine for the company's Margam "B" power station. It will be designed for a live steam pressure of 3000 lb per square inch gauge at a temperature of 1050 deg. Fah. After reheating the exhaust steam will be discharged into the existing 600 lb per square inch gauge steam main. A maximum quantity of 240,000 lb per hour of steam will be supplied from a Benson boiler and under these conditions an alternator output of 9250kW will be available for the steel works. A special design of double casing turbine will be adopted because of the high pressure and temperature. The turbine will be designed in conjunction with Brown, Boveri and Co., of Baden, Switzerland, and will be manufactured at Hartlepool.

Miscellanea

WOOD PULP BOARD WASHERS.—In order to provide an economic sealing means for such things as screw topped containers, where the qualities of rubber or leather washers are not necessary, the Tresises Drip Mat Company, Moor Street Works, Burton-on-Trent, is now making washers of wood pulp board.

ANTI-STATIC MOULDINGS.—A range of anti-static rubber mouldings which has been developed by the Reliance Rubber Company, Cleveland Road, Hemel Hempstead, are stated to have a resistance of 10,000 ohms per cubic centimetre. These mouldings are available as ordinary mechanical components or as precision mouldings made to dimensioned limits of 0·002in.

SMALL BENDING MACHINE FOR CONDUIT TUBES.—A portable bending machine developed for small contractors, which is being marketed by The General Electric Company, Ltd., can be carried in a tool bag. It has been produced primarily for bending conduit tubes of $\frac{5}{8}$in and $\frac{3}{4}$in diameter and can be fixed to a bench or bolted to the leg of a standard tripod vice. Conventional benders normally effect a bending radius of three- or three-and-a-half times the diameter of the tube, but this bender, by the substitution of a smaller former supplied as an extra, can reduce this radius to 2in. The bender is fitted with a pressure roller in advance of the usual guide roller.

WRECK RETURNS.—Lloyd's Register of Shipping has issued its returns of merchant ships totally lost, broken up, &c., for the quarter ended March 31, 1956. Of the world total of 49 steamships and motorships of 74,320 tons gross lost consequent upon casualty, 8 ships of 8196 tons belonged to Great Britain and Northern Ireland and 2 ships of 52 tons to the other Commonwealth countries. The corresponding figures for merchant ships lost not consequent upon casualty are 93 ships of 163,044 tons, 40 ships of 106,311 tons and 7 ships of 2840 tons respectively.

SCREW PUMPS.—Positive displacement, self-priming screw pumps are now being made by Hamworthy Engineering, Ltd., Poole, Dorset, for marine and industrial uses. The range of sizes made covers from two-screw designs of 30 gallons per hour up to three-screw designs of 66,000 gallons per hour capacity. The smaller sizes of these pumps operate at pressures up to 1500 lb per square inch and the larger sizes 300 lb per square inch. For normal pumping duties the pumps are fitted with internal bearings to handle liquids with reasonable lubricating properties; certain sizes are, however, available with outside bearings and steam jacketing for handling fluids without any lubricating properties.

PROCESS TIMER.—The synchronous motor-driven process timer made by Venner, Ltd., New Malden, Surrey, now incorporates a push-button for repeating a set timing period mechanically. This instrument repeats the set timing period each time the push-button is pressed. To set the timer the pointer is turned to the required period and secured by means of a knurled locking ring; on pressing the centre push-button the timing period commences. At the end of the period the timer accurately resets, ready to repeat the period when the push-button is again pressed. The push-button revolves whilst the timer is running and incorporates an arrow to indicate the unexpired time. This instrument is available with seven timing ranges from 3–60 seconds to 2–40 hours.

DEFENCE RESEARCH IN AUSTRALIA.—Dr. F. A. Fox, Deputy Chief Superintendent of the Defence Standards Laboratories at Melbourne, is on a visit to the United Kingdom and has brought with him a forty-five-minute 10mm colour sound film describing the work of the three main laboratories of the Department of Supply—the Defence Standards Laboratory, the Aeronautical Research Laboratory, and the Weapons Research Establishment. The subjects are widely varied, including fatigue tests on aircraft wings, the development for paints with high temperature qualities (including butyl titanate) and resistant to marine growths, and the flying of "Sindivik" drones. The film is available to universities and other interested bodies.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—At a meeting of the Institution of Engineers and Shipbuilders in Scotland, held on November 20, Messrs. A. J. Johnson, B.Sc. (Eng.), Ph.D., and P. W. Ayling, B.Sc., read a paper entitled "Some Observations on Local Vibration." The problem is outlined and to assist in an understanding of the mechanics which govern local vibrations the various forms of ship vibration are broadly grouped into a number of categories. This is followed by a recapitulation of published information having a direct bearing on the subject. A number of typical examples of local vibration, including deckhouse vibration in a twin-screw passenger liner and transverse engine and panel vibration in diesel tugs are described and serve to clarify certain basic principles and also to illustrate the importance of correct analysis before corrective measures can be defined. Some generalisations are made regarding the diagnosis and cure of local vibration and the special problems associated with high-powered ships.

TRAINING SCHOOL FOR APPRENTICES.—A new craft training school for apprentices employed by British Oxygen Engineering, Ltd., was recently opened at Angel Road, Edmonton, by Mr. Robert Carr, the Parliamentary Secretary to the Ministry of Labour. This training school is completely separate from the firm's production workshops and is intended to provide new apprentices with a knowledge and appreciation of basic engineering craft skills. It will also be used for advanced craft training and also for third year apprentices to ensure that experience gained in the previous two years in the workshops is firmly established, and for the teaching of new developments. The school building comprises a machine shop, fitting sections and a lecture room, and the shops are laid out to enable the wide range of work in plant, industrial, medical and aircraft fields to be covered. The school can also be used for intensive courses for the up-grading of fitters, machinists and inspectors, and for the teaching of new techniques to staff in general.

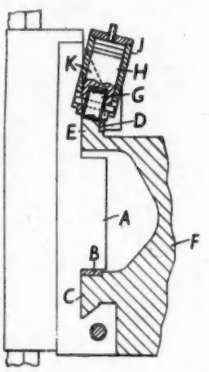
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MACHINE TOOLS

759,046. November 11, 1953.—VERTICAL BORING, DRILLING, TURNING MACHINES, Webster and Bennett, Ltd., Foleshill, Coventry. (*Inventor: Denis Ward Bennett.*)

The invention relates to vertical boring, drilling, turning and like machine tools in which a tool-carrying saddle is slidably mounted on the front face of a horizontal guide provided with upper and lower tracks on which the saddle is supported. In such a machine the weight of the saddle is carried by the lower track, and the upper track is arranged to prevent tilting of the saddle about the lower track. According to the invention, the upper track, or an additional adjacent and parallel upper track on the guide, is inclined transversely and a roller or rollers carried by the saddle co-operate with the inclined track, the roller or rollers being movable relative to the saddle to apply a lifting force. In a known construction the saddle *A* is provided with an adjustable strip *B* of metal or other wear-resisting material through which the saddle can be supported on the lower track *C*. A similar adjustable strip *D* is also provided on the saddle for the rear side of the upper track *E*, or the guide *F*. In applying the invention to such a construction as illustrated in the drawing, there is at each end of the saddle a roller *G* supported on the upper edge of the upper track *E*. Each roller is carried by a piston *H* contained in a cylinder *J* which is formed on a yoke *K* secured to the saddle. The pressure between the saddle *A* and the lower track *C* is reduced to any desired extent by pressure of a fluid, liquid or air, admitted to the upper ends of the cylinders *J* through pipes. Further the upper edge of the upper track *E* is inclined transversely so that the interaction of the rollers *G* and the edge can reduce the pressure between the rear side of this track *E* and the adjustable strip *D* on the saddle. A modified construction is also shown in the specification.—*October* 10, 1956.



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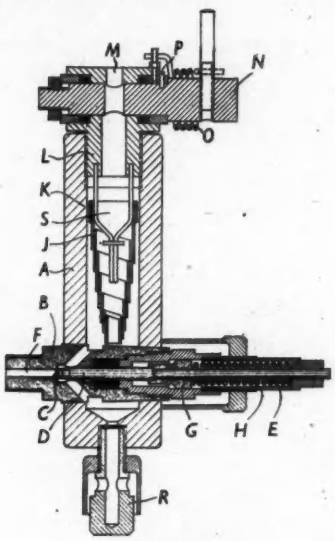
INTERNAL COMBUSTION ENGINES

759,726. November 2, 1954.—IMPROVED STARTING DEVICE, Erich Puls, a partner, Technisches Bureau "Hansa," 139, Weidenbaumsweg, Hamburg-Bergedorf, Germany.

The invention relates to a starting device for internal combustion engines. It differs from known devices in that the combustible ignition charge consists of nitro-cellulose and is provided in a chamber communicating with the engine cylinder through a valve controlled passage. In the drawing one constructional form of the invention is shown. The chamber *A* embodies near one end a valve housing *B* by which it is secured to the engine cylinder. The valve consists of a cone-shaped head *C* and a shank *D* which passes through a sealing element and a control spring *E* which holds the valve in the closed position against the normal combustion pressure in the working cylinder. Since the cross-section of the shank is larger than that of the head, the valve only opens when the pressure of the gas produced in the chamber *A*, which acts on the area differential between the head and the shank, is larger than the force of the spring. Since the cross-section of the passage-way *F* leading into the working cylinder is substantially the same as the cross section of the head *C*, the pressure of the gas flowing through the passage into the cylinder after opening of the valve also acts on the valve shank and on the total cross-section available of the valve. The shank *D*, therefore, moves further from the valve seat than would apply in the case of a normal back pressure valve. Care must, therefore, be taken that the opening of the valve is not so great that the individual turns of the spring can be forced together. For this reason the valve incorporates means for limiting the movement, comprising a collar *G* on the shank which strikes against the spring sleeve *H* and prevents further movement of the valve. The passage *F* is preferably so long that some throttling of the outflowing gases is produced. The ignition charge *J* in the chamber *A* consists of a nitro-cellulose strip in roll form which is arranged in an outer sleeve *K* of nitro-cellulose strip and the roll can be withdrawn in spiral form in the manner of an involute spring. Thereby the result is obtained that the outer surface of the ignition charge spreads as far as possible and uniformly inside the chamber *A*. The ignition charge is secured to a headpiece *L* which closes the chamber *A* at the top and is provided with a bore *M* and a



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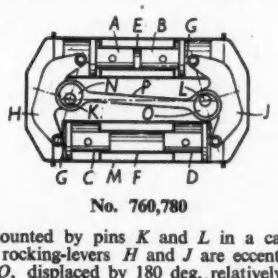
self-closing cock *N* which can be rotated against the spring *O* to a stop *P* so that the bore in the headpiece coincides with that of the cock *N*. A safety relief device *R* is fitted to the base of the chamber *A* to release the gas in the event of faulty operation. In the condition shown in the drawing, an ignited match dropped through the bore *M* passes into the internal space *S* of the ignition charge *J* and the cock *N* is closed. The match ignites the charge at its upper end, whereby the development of pressure gas is started. Since the gas surrounds the ignition body on all sides uniformly, the heat and the gas pressure rise extremely rapidly so that the pressure of the valve spring *E* is overcome and the gases enter into the working cylinder to move its piston.—*October* 24, 1956.

760,780. July 30, 1954.—COMBINED ENGINE AND AIR COMPRESSOR ASSEMBLY, Hans Petersen, 212, Hauptstrasse, Surth-on-Rhine, Germany.

Referring to the drawing, differential pistons *A*, *B*, *C* and *D* are arranged in pairs to operate in opposition in cylinders *E* and *F* parallel to and adjacent one another. The differential pistons *A* and *C*, and also *B* and *D*, are connected to one another by identical connecting rods *G* and double-armed rocking-levers *H* and *J*, respectively, the levers



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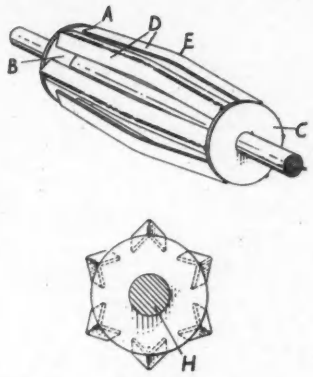
being mounted by pins *K* and *L* in a casing *M*. On the rocking-levers *H* and *J* are eccentric discs *N* and *O*, displaced by 180 deg. relatively to one another. In this manner, the oppositely directed oscillating motion of the rocking-levers *H* and *J* becomes a similarly directed motion of the eccentric discs *N* and *O* and a synchronising rod *P* is mounted on the discs. The constructional form of the driving mechanism is shown in six modified forms in the specification.—*November* 7, 1956.

TRANSPORTERS AND CONVEYORS

758,690. April 23, 1954.—ROLLER FOR BELT CONVEYORS, Phillip Dennis Fernandes Ferreira, Wyn Lodge, Wysall, Nottinghamshire.

The invention relates to an improved guide roller for belt conveyors and has particular, but not exclusive reference to elevator conveyors employed for agricultural and similar purposes. An object of the invention is to avoid creeping of the belt. Referring to the drawing, a conveyor belt guide roller *A* comprises a pair of end discs *B* and *C*, spanned by lengths of angle iron *D* laterally spaced in cylindrical formation. Each angle iron is preferably curved to have a



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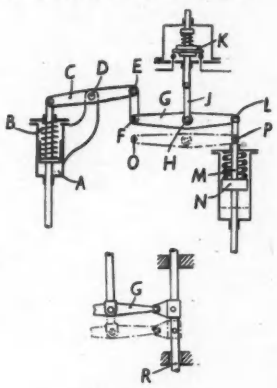
central crown *E*. In use the guide roller will have a good grip on the belt by virtue of the fact that the only contact of the guide roller with the belt is along the corner edges of the angle irons and as these corner edges are somewhat rounded there is little or no danger of them cutting into the belt. The crown formation of each angle iron tends to maintain the belt in a central path of travel.—*October* 10, 1956.

ROAD TRANSPORT

759,586. April 9, 1952.—INDICATING DEVICES ON TURBINE-DRIVEN VEHICLES, Regie Nationale des Usines Renault, of 8/10, Avenue Emile Zola, Billancourt (Seine), France.

In road or rail turbine vehicles, the speed of the turbine increases in proportion to that of the vehicle, or is a direct function of it. It may happen, therefore, particularly if the vehicle is a locomotive, that its speed, on a steep decline, reaches a value which is higher than that which corresponds to the rated maximum speed of the turbine and exposes the latter to the danger of bursting. The invention is an improvement to indicating devices, the object of which is to indicate to the driver that the critical



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speed of the turbine has been reached. Referring to the drawing, there is shown a cylinder *A*, the piston of which, acted on by a spring *B*, is subjected to the action of air or liquid pressure depending on the speed of the turbine. The piston, which moves upwards with an increase of turbine speed, operates on a lever *C* pivoted at *D* and the end *E* of which acts on the end *F* of a balance member *G*, the centre *H* of which is connected by the rod *J* to the switch *K* which actuates a sound or other signal. The end *L* of the balance member *G* is connected to a rod *M* of a piston *N* subjected to air or liquid pressure, depending upon the position of the lever controlling, for example, the fuel supply to the turbine. A downward movement of piston *N* corresponds to a reduction in the fuel supply to the turbine. The members *M* and *N* may also be replaced by a rod *R*, the position of which depends on that of the control lever to which the rod is mechanically connected. The switch *K* will be closed when the ends *F* and *L* of the balance member *G* occupy the positions *O* and *P*, in other words, when the speed of the turbine exceeds a permitted safe value corresponding to the actual speed of the vehicle, the control lever of the fuel supply to the turbine having been set for example, at its throttled position. This will be produced in the event of racing of the vehicle on a down gradient, for example. The signal will be interrupted when the speed of the turbine drops again to the permitted value.—*October* 24, 1956.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Mon., Dec. 3.—LEEDS BRANCH : Great Northern Hotel, Leeds, "Water Heating," L. L. Hughes, 7.30 p.m.——N.E. LONDON BRANCH : Angel Hotel, Ilford, "Reclamation by Metal Spray," B. H. Devis, 7.30 p.m.——SHEFFIELD BRANCH : Royal Victoria Station Hotel, Sheffield, "Mineral Insulated Cables for Wiring and Warming," R. J. Cotton, 7.30 p.m.

Tues., Dec. 4.—OXFORD, READING AND DISTRICTS BRANCH : The University, London Road, Reading, "The Industrial Uses of Isotopes," E. W. Jones, 7.15 p.m.——TYNESIDE BRANCH : Visit to the Evening Chronicle printing works, 7.30 p.m.——W. LONDON BRANCH : Windsor Castle Hotel, 134, King Street, Hammersmith, "Railway Electrification," R. W. V. Morton, 7.30 p.m.

Wed., Dec. 5.—N. LONDON BRANCH : Queens Head, 677, Green Lanes, Harringay, N.4, "Control of Oil Burners and Building Heating," S. O. Grant, 7.45 p.m.——PRESTON BRANCH : R.A.F.A. Club, East View, Preston, "Planning a Lighting Installation," A. G. Smith, 7.30 p.m.

Thurs., Dec. 6.—GLASGOW BRANCH : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Lighting of Small Factories," J. S. McCulloch, 8 p.m.——LUTON BRANCH : Chamber of Commerce, George Street West, Luton, "Scope and Limitations of Industrial Psychology," D. B. A. Brasier-Creagh, 8 p.m.——SOUTHAMPTON BRANCH : Polygon Hotel, Southampton, "Installation and Operation of a Television Station," E. P. D. Metcalf, 8 p.m.——S. LONDON BRANCH : Half Moon Hotel, Broad Green, Croydon, "Motor Maintenance," P. H. Usher, 8 p.m.

Fri., Dec. 7.—LIVERPOOL BRANCH : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Modern Short-Circuiting Testing Technique," J. G. P. Anderson, 7.30 p.m.

BELFAST ASSOCIATION OF ENGINEERS

Wed., Dec. 5.—College of Technology, Belfast, Annual Informal Meeting, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Dec. 5.—S. WALES SECTION: College of Technology and Commerce, Cathays Park, Cardiff, "Voltage Stabilisation," F. A. Benson, 6.30 p.m.

Thurs., Dec. 6.—N.W. SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, "Electronic Automation Applied to the Wind Tunnel," D. S. Wilde, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., Dec. 1.—Caxton Hall, Westminster, London, S.W.1, "The Use of Probe Rockets," C. A. Cross, 6 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Dec. 4.—Church Institute, Hull, "Calcium Carbide Production," J. B. Moller, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Dec. 3.—LEEDS CENTRE : Electricity Board Lecture Theatre, Ferensway, Hull, "An Architects' Approach to Lighting Design," G. Grenfell Baines, 7 p.m.

Wed., Dec. 5.—EDINBURGH CENTRE : Y.M.C.A., 14, South St. Andrews Street, Edinburgh, "Lighting of Small Factories," J. S. McCulloch, 6.15 p.m.——NEWCASTLE UPON TYNE CENTRE : Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, "Foundations for Inspiration at Home," T. O. Freeth, 6.15 p.m.

Thurs., Dec. 6.—CARDIFF CENTRE : S. Wales Electricity Board's Demonstration Theatre, The Hayes, Cardiff, "Lighting as a Basis for Design," D. Phillips, 7 p.m.——GLASGOW CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Lighting of Small Factories," J. S. McCulloch, 6.30 p.m.——NOTTINGHAM CENTRE : Electricity Service Centre, Smithy Row, Nottingham, "Lighting at London Airport," J. G. Holmes, 5.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Nov. 30.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Canning," R. F. Rooke and Miss Christine Macnab, 7.30 p.m.

Tues., Dec. 4.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Refrigeration and the Heat Pump," Sir Oliver Lyle, 7 p.m.

Wed., Dec. 5.—E. MIDLANDS BRANCH : County Hotel, Theatre Square, Nottingham, Ladies Film Evening, 7 p.m.——SOUTHERN BRANCH : Polygon Hotel, Southampton, "Application of Plastics in Industry" C. L. Child, 7.30 p.m.

Fri., Dec. 7.—PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, "Control of Loads on the Grid," 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Mon., Dec. 3.—SHEFFIELD BRANCH : College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, "Some Aspects of Research and their Application to the Foundry Industry," A. H. Sully, 7 p.m.

Tues., Dec. 4.—SLOUGH SECTION : High Duty Alloys, Ltd., Slough, Open discussion on "Dimensional Accuracy of Castings," W. L. King, J. L. Rice, H. J. Sharpe, and A. Taylor, 7.30 p.m.

Thurs., Dec. 6.—LONDON BRANCH : Institute of Metals, 17, Belgrave Square, London, S.W.1, "Founding of Magnesium," E. F. Emley, 6.30 p.m.——STOKE SECTION : Stipendiary Court Room, Hanley, "Mechanised Foundries," H. A. Fox, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

To-day, Nov. 30.—MERSEYSIDE AND N.W. SECTION JUNIOR LECTURE : Municipal College, Barrow-in-Furness, "Automatic Boiler Control," W. Young, 7 p.m.

Thurs., Dec. 6.—N.E. COAST SECTION : Technical College, Sunderland, "The Modern Marine Steam Turbine," J. H. Gooch, 4 p.m.

INSTITUTE OF METALS

Tues., Dec. 4.—OXFORD LOCAL SECTION : Cadena Café, Cornmarket Street, Oxford, Films of Scientific Interest, 7 p.m.

Thurs., Dec. 6.—Chemical Department, Woodland Road, Bristol, Joint Meeting with the Chemical Engineering and Corrosion Groups of the Society of Chemical Industry, 6.30 p.m.

Thurs., Dec. 6.—BIRMINGHAM LOCAL SECTION : Exchange and Engineering Centre, Stephenson Place, Birmingham, Students Evening, Competition for the Dorothy Pile Trophy, 6.30 p.m.——LONDON LOCAL SECTION : 17, Belgrave Square, London, S.W.1, "The Foundry of Magnesium," E. F. Emley, 6.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 5.—26, Portland Place, London, W.1, "Hydraulics of Drilling Mud Flow," Peter W. Cooke, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Dec. 6.—Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Cooling Problems in High-Speed Military Aircraft," Miss B. Shilling, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Dec. 3.—SCOTTISH CENTRE : North British Hotel, Edinburgh, "Road and Rig Testing of Prototype Road Transport Vehicles, and Their Components" J. H. Alden, 7 p.m.

Tues., Dec. 4.—EASTERN CENTRE : Lion Hotel, Cambridge, Address by a Member of the Local Police Force, 7.30 p.m.

Wed., Dec. 5.—E. MIDLANDS CENTRE : Mechanics' Institute, Nottingham, "Exhaust Brake Design and Operation," A. G. Slee, 7.30 p.m.

Thurs., Dec. 6.—WESTERN CENTRE : Royal Hotel, Bristol, "Maintaining the Local Light Vehicle," W. F. Turton, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., Dec. 10.—NORTHERN CENTRE : N.E. Electricity Board's Lecture Theatre, Carliol House, Newcastle, "Baling for Silage," R. M. Chambers, 6.45 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Tues., Dec. 4.—Geological Society, Burlington House, London, W.1, "High Intensity Combustion in Chemical Engineering," R. P. Fraser, 5.30 p.m.——N.W. BRANCH : Birkenhead Technical College, Chester, "Centrifugation as a Unit Operation," F. A. Groves, 7.15 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day., Nov. 30.—YORKSHIRE ASSOCIATION: Grand Hotel, Sheffield, "The Analysis of Prestressed Concrete Structural Members and the Application of Recent Research," P. B. Morice, 6.15 p.m.

Tues., Dec. 4.—WORKS MEETING : Great George Street, Westminster, London, S.W.1, "The Design and Construction of a Laboratory for Research in Underwater Ballistics," C. L. Champion, R. J. H. Hancock and W. Woolfson, 5.30 p.m.

Thurs., Dec. 6.—Joint Meeting with the Société des Ingénieurs Civils de France : Great George Street, Westminster, London, S.W.1, "A French Dual Purpose Scheme : the Durance Project and the Serre-Poncon Dam," R. Giguet, 5.30 p.m.——N.W. ASSOCIATION : Engineers' Club, Albert Square, Manchester, "The Construction of Middleton Connecting Sewer in North Manchester," E. H. Collier, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Dec. 3.—RADIO AND MEASUREMENT SECTIONS : Savoy Place, London, W.C.2, "Electronics and Automation : The Use of Nucleonic Devices," Dennis Taylor, 5.30 p.m.——S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, "Crystal Palace Television Transmitting Station," F. C. McLean, A. N. Thomas and R. A. Rowden, 6 p.m.

Tues., Dec. 4.—S.E. SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, "Temperature Rises in Electrical Machines on Variable Load and with Variable Speed," A. Tustin and J. J. Bates, 7 p.m.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, "The Absolute Calibration of Voltage Transformers," W. K. Clothier and L. Medina, 5.30 p.m.

Wed., Dec. 5.—S.W. SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, "Power System Protection, with Particular Reference to the Application of Junction Transistors to Distance Relays," C. Adamson, 7 p.m.

Thurs., Dec. 6.—ORDINARY MEETING : Savoy Place, London, W.C.2, "The Measurement of Earth-Loop Resistance," G. F. Tagg, 5.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Dec. 4.—39, Elmbank Crescent, Glasgow, "Some Observations on Local Vibrations," A. J. Johnson and P. W. Ayling, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Wed., Dec. 5.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Storage of Oil Fuel," T. Chippindale, 6 p.m.

Wed., Dec. 5.—E. MIDLAND BRANCH : College of Arts and Crafts, Waverley Street, Nottingham, "An Investigation of the Possibilities of Partial Pre-Fabrication of Heating Plant," J. L. Burgin and N. Jackson, 6.45 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Thurs., Dec. 6.—YORKSHIRE AND LINCOLNSHIRE BRANCH : Grammar School, Goole, "The Impact of Laboratory Engineering on Roadmaking," G. R. Forrester, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 30.—GENERAL MEETING IN CONJUNCTION WITH THE EDUCATION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "The American System of Education and Training of Mechanical Engineers," H. S. Arms ; "The Education of Engineers in European Countries," S. J. Davies, 6 p.m.——WESTERN A.D. CENTRE : Royal Hotel, Bristol, "Heating and Ventilating Systems for Passenger Service Vehicles," T. R. Cave-Brown-Cave, 6.45 p.m.

Mon., Dec. 3.—N.E. BRANCH : Neville Hall, Newcastle upon Tyne, "A Standard Gas Turbine to Burn a Variety of Fuels," G. B. R. Feilden, D. R. Thorn and M. S. Kemper, 6 p.m.——LUTON A.D. CENTRE : Assembly Hall, Town Hall, Luton, "Experiences During Forty Years of Automobile Design," A. G. Booth, 7.30 p.m.

Tues., Dec. 4.—EASTERN BRANCH : Sun Hotel, Hitchin, "Fatigue of Metals," J. A. Pope, 7.30 p.m.——COVENTRY A.D. CENTRE : Leofric Hotel, Coventry, "Standard Procedure for Brake Testing," F. W. Bromley, 7.15 p.m.——N.W., A.D. CENTRE : Engineer's Club, Albert Square, Manchester, "Automobile Design from the Safety Angle To-day and Tomorrow," A. Bourne, 7.15 p.m.

Wed., Dec. 5.—E. MIDLAND BRANCH : College of Technology, Loughborough, "Nuclear Reactor Fundamentals," B. L. Goodlet, 7 p.m.——SOUTHERN BRANCH: College of Technology, Portsmouth, "Power Station Auxiliary Plant," Geoffrey F. Kennedy and F. J. Hutchinson, 6.30 p.m.——LONDON GRADUATES' SECTION : Visit to Dunlop Rubber Co., 7 p.m.

Thurs., Dec. 6.—EDUCATION GROUP DISCUSSION : 1, Birdcage Walk, Westminster, London, S.W.1, "The Sphere and Duties of the Industrial Education Officer," 6.45 p.m.——N.W. BRANCH : Engineers' Club, Albert Square, Manchester, "Problems of High Speed Flight," R. F. Creasey, 6.45 p.m.——E. MIDLANDS GRADUATES' SECTION : Gas Showrooms, Peterborough, Film Show, 7.15 p.m.——YORKSHIRE GRADUATES' SECTION : The University, St. Georges Square, Sheffield, "Roof Supports in Coal Mines," S. G. Harris, 6.30 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Dec. 6.—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Some Problems in Design and Use of Free Piston Gas Generators On Board Ships," A. Augustin Normand and Monsieur Bartholon, 4.45 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Tues., Dec. 4.—COVENTRY GRADUATES SECTION : Craven Arms, High Street, Coventry, Film Evening, 7.15 p.m.

Wed., Dec. 5.—WESTERN SECTION : University Engineering Laboratories, University Walk, Bristol, "Problems and Prospects of British Aviation," P. G. Masefield, 7.15 p.m.——SOUTHERN SECTION : Town Hall, Christchurch, "The Development and Achievement of the Vickers Viscount," A. H. C. Greenwood, 7.15 p.m.——S. ESSEX SECTION : Mid-Essex Technical College, Chelmsford, "Future Trends in Technical Education," F. Bray, 7.30 p.m.——NOTTINGHAM SECTION : Victoria Station Hotel, Milton Street, Nottingham, "Factory Fundamentals for a Small Factory," Hal Gutteridge, 7 p.m.——LIVERPOOL SECTION : Central Libraries, William Brown Street, Liverpool, "The Practical Application of Production Engineering Research," D. F. Galloway, 7.30 p.m.——HALIFAX GRADUATE SECTION : Technical College, Huddersfield, "Organisation Requirements for the Production of Modern Agricultural Machinery," 7.30 p.m.

Thurs., Dec. 6.—READING SECTION : Great Western Hotel, Reading, "The Properties of Pure Molybdenum Disulphide and its Application to Production Engineering," H. Peter Jost, 7.30 p.m.——LONDON SECTION : Powers-Samas Accounting Machines, Ltd., Aurelia Road, Croydon, Surrey, "Electronics as an Aid to Production with Special Reference to the Aircraft Industry," T. A. Waite, 7 p.m.——LONDON GRADUATE SECTION : Visit to the Royal Mint, Tower Hill, London, E.C.3, 2 p.m.——PETERBOROUGH SECTION : White Lion Hotel, Church Street, Peterborough, "Nuclear Power and its Effect on the Production Engineer," I. Munro, 7.30 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Nov. 30.—YORKSHIRE BRANCH : Grand Hotel, Sheffield, "The Analysis of Prestressed Concrete Structural Members and the Application of Recent Research," P. B. Morice, 6.15 p.m.

Tues., Dec. 4.—NORTHERN COUNTIES BRANCH : Cleveland Scientific and Technical Institution, Middlesbrough, "The Advantages and Disadvantages of Structural Steelwork, Reinforced Concrete and Prestressed Concrete," Donovan H. Lee, 6.30 p.m.——N. IRELAND BRANCH : College of Technology, Belfast, "Tubular Steel Structures," R. G. Taylor, 6.45 p.m.

Wed., Dec. 5.—NORTHERN COUNTIES BRANCH : Neville Hall, Newcastle, "The Advantages and Disadvantages of Structural Steelwork, Reinforced Concrete and Prestressed Concrete," Donovan H. Lee, 6.30 p.m.——YORKSHIRE BRANCH : C.E.A. Offices, Whitehall Road, Leeds, "The Use of Gunite as a Structural Material," T. Whitley Moran, 6.30 p.m.

Fri., Dec. 7.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION : Exchange and Engineering Centre, Stephenson Place, Birmingham, "Some Structural Aspects of Nuclear Reactors," W. H. Chilton, 6.30 p.m.——S.W. COUNTIES BRANCH : Duke of Cornwall Hotel, Plymouth, "Plymouth Breakwater Review," T. W. Riley, 6 p.m.——W. COUNTIES BRANCH : The University, Bristol, "Some Structures Involving Unusual Design Problems," C. E. Saunders, 6 p.m.

IRON AND STEEL INSTITUTE

Wed., Dec. 5.—IRON AND STEEL ENGINEERS GROUP: 4, Grosvenor Gardens, London, S.W.1, "Blowers for Use in Iron and Steel Works," F. J. Potter and L. Duffy, 10.30 a.m. to 12.45 p.m., "Gas and Air Compressors," V. Barnett, 2 p.m. to 4 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 30.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Annual General Meeting, 7 p.m.

Wed., Dec. 5.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, "Work Study," V. N. Picken, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Mon., Dec. 3.—Royal Institution, Colquitt Street, Liverpool, "Some Impressions of a Visit to Russia," A. R. Cooper, 6.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Dec. 7.—Engineers' Club, Albert Square, Manchester, "Mechanical Handling Equipment and its Applications," F. T. Dean, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 30.—Mining Institute, Newcastle upon Tyne, "The Nominal Cleavage Strength of Steel and its Importance for Welded Structures," T. Noren, 6.15 p.m.

Wed., Dec. 5.—STUDENT SECTION : Bolbec Hall, Newcastle upon Tyne, "Deep Sea Trawlers," J. M. Tanton, 6.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Dec. 4.—N.W. BRANCH : College of Technology, Sackville Street, Manchester, "The Use of Reinforced Concrete in the Construction of Atomic Energy Establishments," D. R. R Dick, 6.45 p.m.

Wed., Dec. 5.—N.W. BRANCH : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "The Use of Reinforced Concrete in the Construction of Atomic Energy Establishments," D. R. R. Dick, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Fri., Dec. 7.—GRADUATES' AND STUDENTS' SECTION : 4, Hamilton Place, London, W.1, Film Show, 7.30 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Dec. 3.—ORDINARY GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, "The Chartered Surveyor in Local Government," H. E. G. Stripp, 5.45 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., Dec. 6.—CORROSION GROUP : Visit to the Metallurgical Laboratories and Precision Foundry of Bristol Aero-Engines, Ltd., 2.30 p.m. ; The University, Woodland, Woodland Road, Bristol, "Corrosion Fatigue," T. D. Weaver, "Stress Corrosion," K. R. Wilson, 6 p.m.——ROAD AND BUILDING MATERIALS GROUP : 14, Belgrave Square, London, S.W.1, "New and Revised Test Methods," 6 p.m.

SOCIETY OF ENGINEERS

Mon., Dec. 3.—Geological Society, Burlington House, Piccadily, London, W.1, "The Submarine : Past, Present and Future," Sir Charles S. Lillicrap, 5.30 p.m.

WOMEN'S ENGINEERING SOCIETY

Thurs., Dec. 6.—LONDON BRANCH : Hope House, 45, Great Peter Street, Westminster, London, S.W.1, Forum on Technical Education, 7 p.m.

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